City of Plantation

Final Report

Advanced Wastewater Treatment Pilot Project

April 2008

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HAZEN AND SAWYER
Environmental Engineers & Scientists

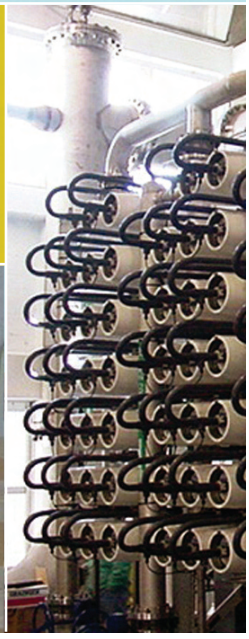

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Table of Contents

O:\41065-003\Wpdocs\Report\R1\Final

Appendices

Tables

O:\41065-003\Wpdocs\Report\R1\Final

Figures

After Page

Acknowledgement

The assistance of the CPWWTF's operation, maintenance and lab staff is gratefully acknowledged.

The following are also gratefully acknowledged for their contribution to the Pilot Program:

- Alpha Valve & Controls, Inc.
- Aquionics
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- Orange County Utilities
- Osmonics
- PB Water
- Separation Processes, Inc.
- South Florida Water Management District
- University of Miami

Executive Summary

As part of an ongoing regional effort to identify feasible alternative water supplies, the City of Plantation (City) and the South Florida Water Management District (District) entered into a cooperative agreement to evaluate recharging the Biscayne Aquifer with highly treated reclaimed water through surface water discharge. Discharging reclaimed water from the City of Plantation Wastewater Facility (CP WWTF) into the East Holloway Canal (EHC), which is part of the Old Plantation Water Control District, is a method of recharging the Biscayne Aquifer. The work associated with this agreement was to evaluate, through literature review and subsequent pilot testing, viable treatment technologies.

The goal of this pilot program was to evaluate the efficacy potential treatment technologies based upon anticipated effluent limits. Upon review of the State and County regulatory requirements and for the purposes of this evaluation, key anticipated effluent limits were utilized to select the treatment schemes piloted, specifically Total Nitrogen (TN) < 1.5 mg/L and Total Phosphorus (TP) < 0.02 mg/L.

Based on the anticipated effluent limits the following three options were chosen to be piloted:

- Membrane Bioreactor Scheme (see Figure 2-1): Primary effluent from the CP WWTF was treated using; Biological Nutrient Removal (BNR), a Membrane Bioreactor (MBR), Reverse Osmosis (RO) and Ultraviolet (UV) disinfection.

- Conventional Treatment Scheme (see Figure 2-2): Nitrified secondary effluent from the CP WWTF was treated using; denitrification sand filters (DSF), Ultrafiltration (UF), RO and UV disinfection.

- Reverse Osmosis Scheme (see Figure 2-3): Nitrified secondary effluent from the CP WWTF was treated using; UF, RO and UV disinfection.

Due to the short duration of the pilot testing effort, the pilot systems were not operated to minimize Operation and Maintenance (O&M) costs, but were operated only to demonstrate each process scheme's ability to meet the stringent TN and TP limits. Based on the pilot test results, all three process schemes appear to be viable options for potential full-scale implementation. As shown in Table 1, all three pilot schemes consistently met

the anticipated TN and TP effluent limits under varying test conditions. Table 2 provides a summary of operating conditions.

Table 1
TN and TP Comparative Results Summary

Average TN									
	MBR		DSF		UF		RO		Test Condition Removal Rate (%)
Component	Inf. (mg/L)	Eff. (mg/L)	Inf. (mg/L)	Eff. (mg/L)	Inf. (mg/L)	Eff. (mg/L)	Inf. (mg/L)	Perm. (mg/L)	
MBR-1	19.7	5.8	-	-	-	-	5.8	1.2	94
MBR-2	19.2	6.0	-	-	-	-	6.0	1.2	94
CONV-1	-	-	11.9	2.3	2.3	2.2	2.2	0.8	93
CONV-2	-	-	11.9	1.1	1.1	1.0	1.0	0.7	94
CONV-3	-	-	11.3	2.9	2.9	2.7	2.7	0.9	92
CONV-4	-	-	10.2	5.4	5.4	4.9	4.9	0.8	92
RO-1	-	-	-	-	11.0	10.5	10.5	1.3	88
Average TP									
MBR-1	2.2	0.3	-	-	-	-	0.3	0.02	>99
MBR-2	2.1	0.1	-	-	-	-	0.1	0.003	>99
CONV-1	-	-	1.9	1.7	1.7	0.6	0.6	0.003	>99
CONV-2	-	-	1.9	1.7	1.7	0.6	0.6	0.003	>99
CONV-3	-	-	1.8	1.6	1.6	0.4	0.4	0.007	>99
CONV-4	-	-	1.5	1.4	1.4	0.1	0.1	0.003	>99
RO-1	-	-	-	-	1.8	1.6	1.6	0.003	>99

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Table 2
Summary of Operating Conditions

Test Condition	Description	Duration Days	BNR + MBR		DSF		UF/RO/ System
			Target Alum Dose (mg/L)	Target Methanol Dose (mg/L)	Target Methanol Dose[(1)] (mg/L)	Target Loading (gpm/sf)	UF Target Alum Dose (mg/L)
MBR-1	Biological Nitrogen and Phosphorous Removal	60	None	None	-	-	-
MBR-2	Biological & Chemical Nitrogen and Phosphorous Removal	7	11	20	-	-	-
CONV-1	Low DSF loading rate w/methanol and alum addition	50	-	-	3.5:1	2	40
CONV-2	Medium DSF loading rate w/methanol and alum addition	10	-	-	3.5:1	3	40
CONV-3	High DSF loading rate w/methanol and alum addition	5	-	-	3.5:1	4	80
CONV-4	Medium DSF loading rate w/methanol and alum addition	5	-	-	3.5:1	3	80-120
RO-1	Bypass DSF-Nitrified Secondary Effluent/UF/RO	10	-	-	-	-	None

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Section 1.0
Introduction

As part of an ongoing regional effort to identify feasible alternative water supplies, the City of Plantation (City) and the South Florida Water Management District (District) entered into a cooperative agreement to evaluate recharging the Biscayne Aquifer with highly treated reclaimed water through surface water discharge. Discharging reclaimed water from the City of Plantation Wastewater Facility (CP WWTF) into the East Holloway Canal (EHC), which is part of the Old Plantation Water Control District, is a method of recharging the Biscayne Aquifer. The work associated with this agreement was to evaluate, through literature review and subsequent pilot testing, viable treatment technologies.

The following summarizes the primary tasks associated with this project:

Phase 1

A. Perform a technical and economic desk-top evaluation of the potential process treatment schemes capable of meeting local and state water quality standards. The goal of this evaluation is to identify the most promising process scheme(s) for piloting.

B. Design a pilot plant for the selected process scheme(s).

C. Prepare an Operation and Monitoring Plan for the pilot plant.

Phase 2

A. Secure, install and operate/monitor the pilot plant with the goal of demonstrating the effectiveness of the process scheme with meeting the desired water quality to be discharged to the EHC. (Note that pilot plant effluent will be discharged to the head of the CP WWTF.)

B. Demobilize the pilot plant and restore the pilot plant site to pre-pilot plant conditions.

C. Prepare a final report summarizing the operation and results of the pilot plant.

This Report addresses Phase 2, Task C. The other tasks are summarized in previously prepared reports/memoranda.

Section 2.0
Goals and Objectives

The goal of this pilot program was to evaluate potential treatment technologies and the feasibility of discharging reclaimed water into the EHC near the CP WWTF based on anticipated effluent limits. The EHC is a Class III surface water which has preliminarily been identified as an impaired water body through the USEPA process. It is expected that permitting of a new discharge into the EHC will be subject to discharge limits developed by the FDEP through the Water-Quality Based Effluent Limitations (WQBEL) and Total Maximum Daily Loads (TMDL) process. The discharge is also expected to have to comply with drinking water standards since the reclaimed water will serve to recharge the ground water. Upon review of the State and County regulatory requirements and for the purposes of this evaluation, the effluent limits shown in Table 2.1 were assumed as the key parameters of concern and were utilized to select the treatment schemes piloted.

Table 2.1
Anticipated Effluent Limits(1)
Key Parameters

Parameter	Concentration
Total Nitrogen	< 1.5 mg/l
Total Phosphorus	< 0.02 mg/l
Total Suspended Solids	< 5.0 mg/l
BOD_5	< 5.0 mg/l
Fecal Coliform	Non-Detectable

(1) Anticipated Effluent Limits based on BC Ch 27, Article V and FAC 62-302.

Based on the anticipated effluent limits shown above, several process treatment schemes were evaluated (desk-top level evaluation) as to their potential for meeting the anticipated effluent requirements. The key effluent criteria that drove the process selection were: Total Nitrogen < 1.5 mg/l and Total Phosphorus < 0.02 mg/l. Although these parameters have been identified as the likely drivers regarding treatment, there are other parameters that will need to be met. The effluent quality was estimated for each of the process schemes and the following three options were chosen to be piloted:

- Membrane Bioreactor Scheme (see Figure 2-1): Primary effluent from the CP WWTF was treated using; Biological Nutrient Removal (BNR), a Membrane Bioreactor (MBR), Reverse Osmosis (RO) and Ultraviolet (UV) disinfection.

- Conventional Treatment Scheme (see Figure 2-2): Nitrified secondary effluent from the CP WWTF was treated using; denitrification sand filters (DSF), Ultrafiltration (UF), RO and UV disinfection.

- Reverse Osmosis Scheme (see Figure 2-3): Nitrified secondary effluent from the CP WWTF was treated using; UF, RO and UV disinfection.

The primary goal of the project was to demonstrate compliance of the process options with the stringent nutrient limits through pilot testing. Based on the pilot results, the merits of each process scheme can be further evaluated for potential full-scale implementation. At that point, additional criteria could be considered such as operational issues, constructability, maintenance and operation of plant during construction, and how to integrate this project with a future plant expansion. Also, a more detailed analysis could be conducted on how to best achieve nutrient removal using existing versus new infrastructure.

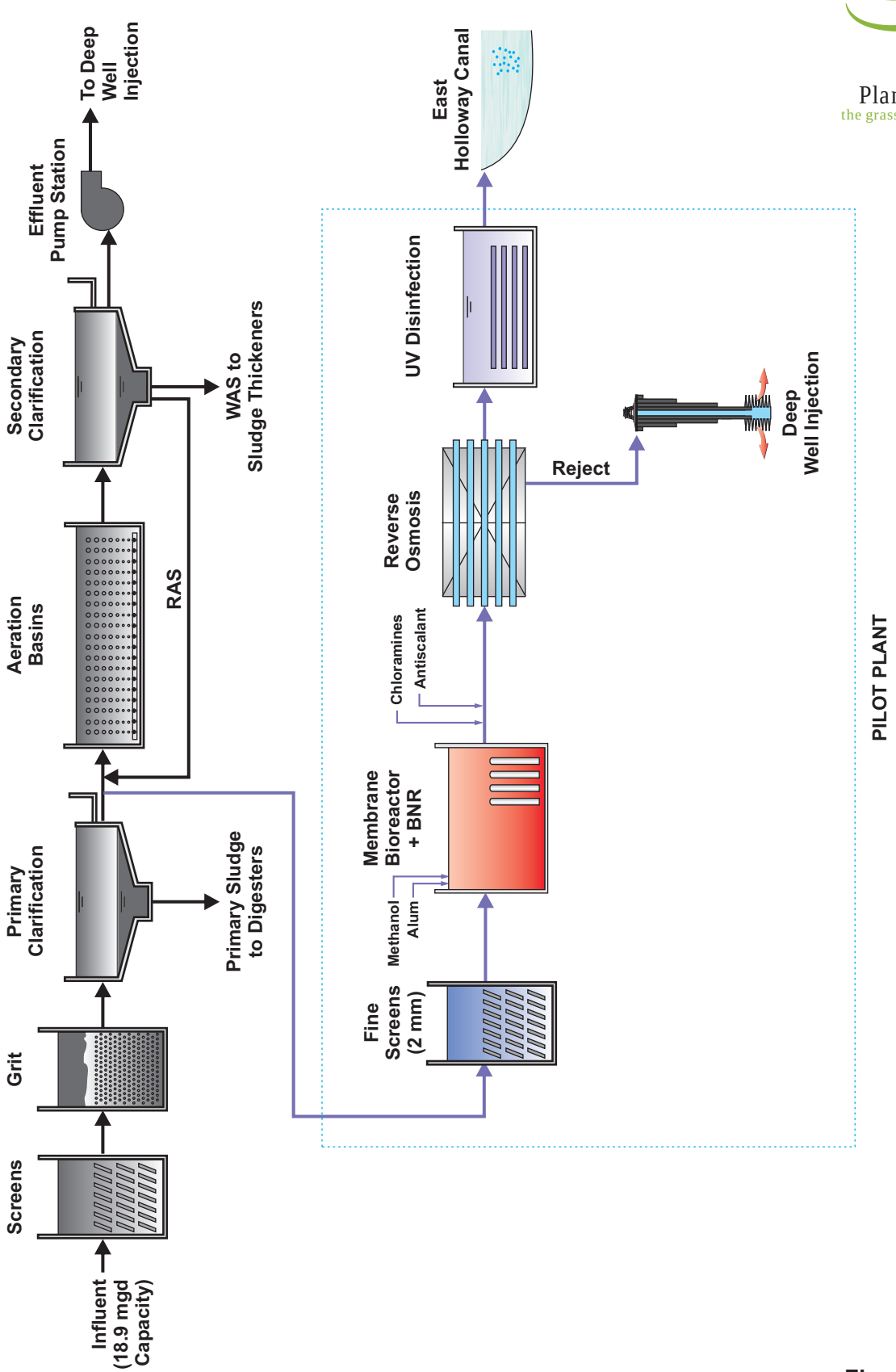

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Figure 2-1
MBR Scheme

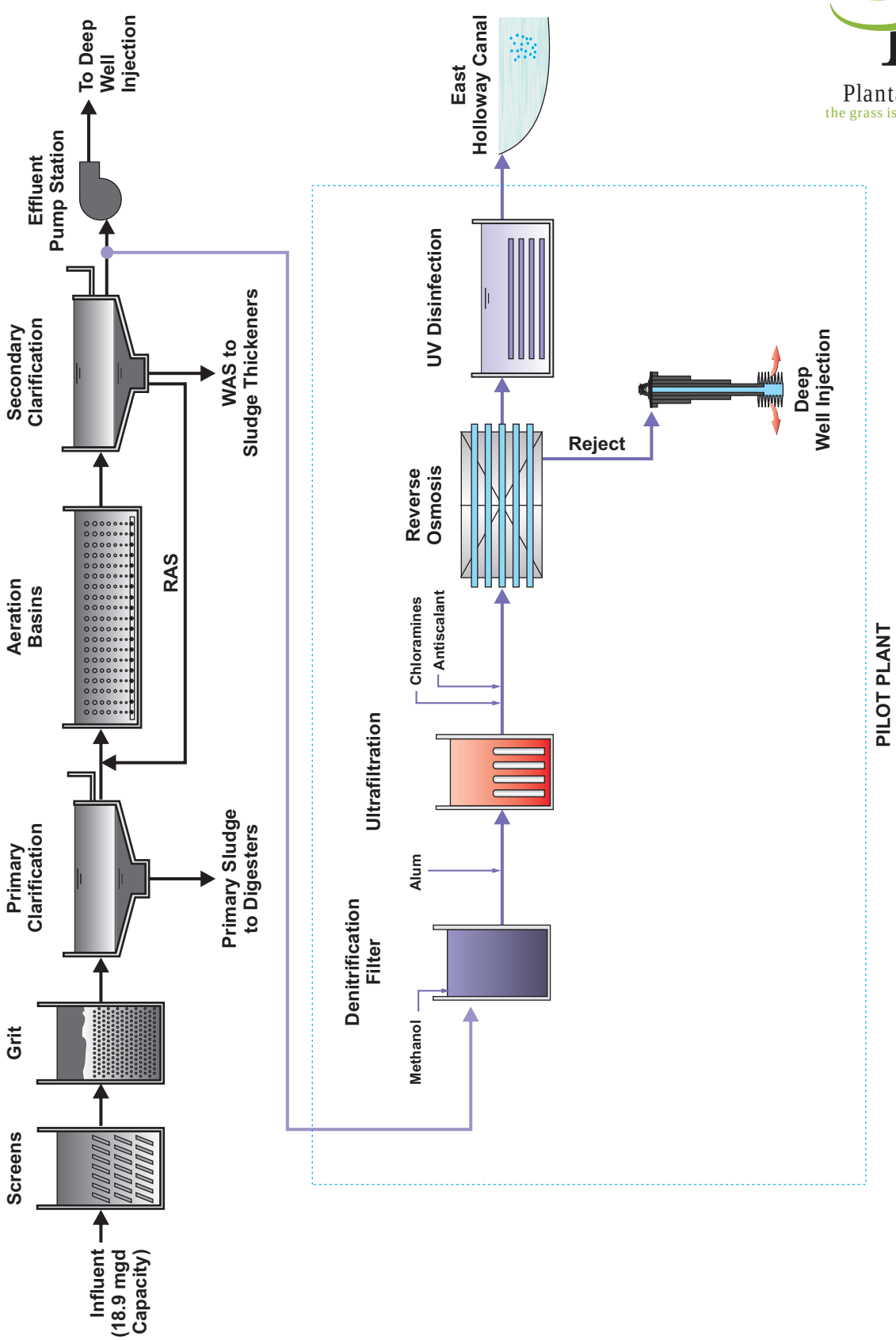

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Figure 2-2
Conventional Treatment Scheme

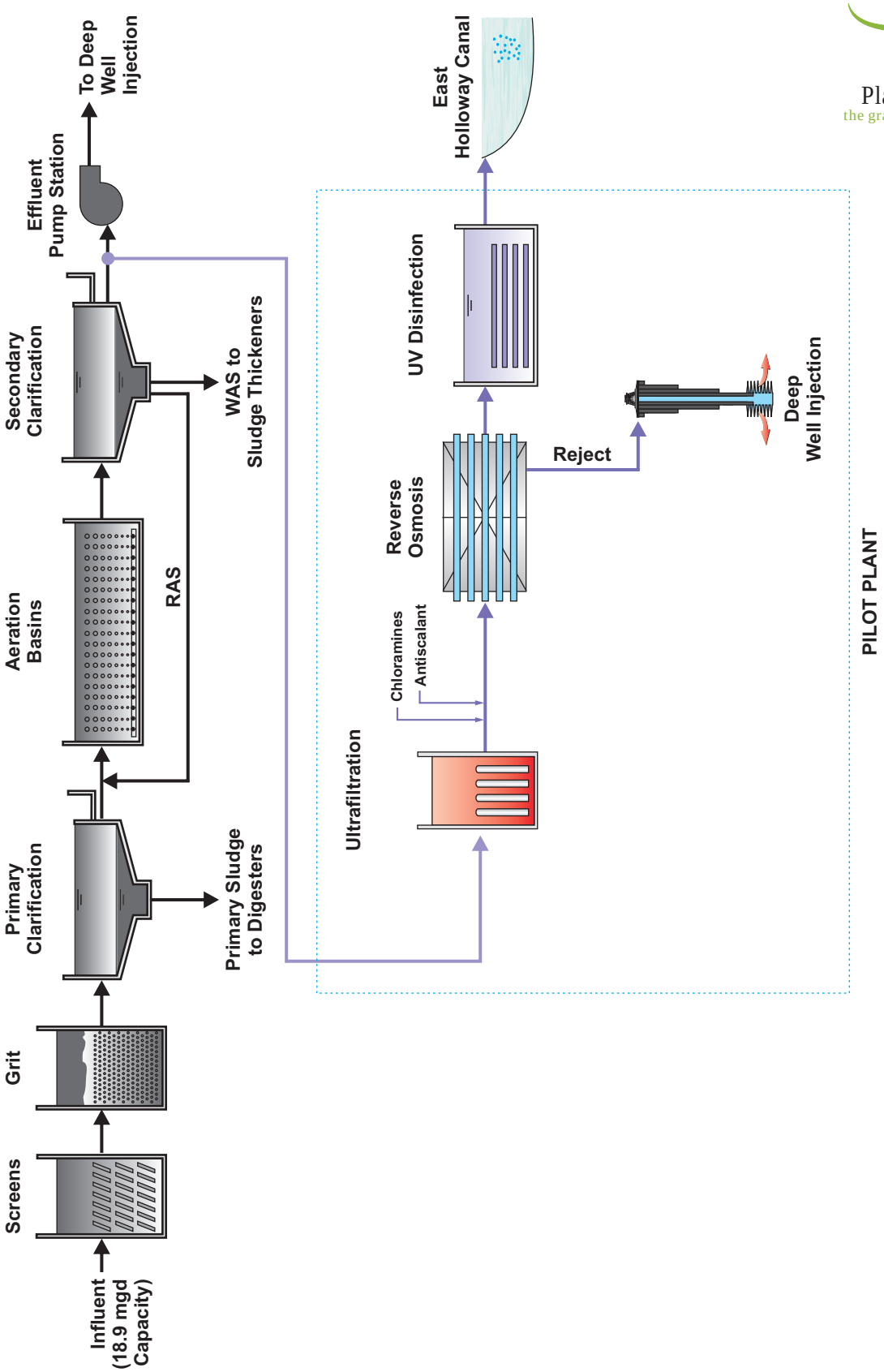

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Figure 2-3
Reverse Osmosis Scheme

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Section 3.0
Testing Program

3.1 Plan of Study

A Pilot Test Program was developed in an effort to focus on meeting the project goals and objectives in an expeditious and phased manner. Although the Test Program was modified during the course of the project, the overall project goal was maintained. The individual Pilot Test Programs for each pilot scheme are summarized in Tables 3.1 and 3.2.

3.1.1 MBR Scheme

The primary goal of this process scheme's testing program was to demonstrate biological nitrogen and phosphorus removal in the MBR followed by treatment using an RO. The BNR process design primarily focused on biological phosphorus removal and not biological nitrogen removal. As a result, nitrogen removal rates in the MBR pilot will be conservative relative to MBRs designed around nitrogen removal. In order to accelerate the biological seeding time in the MBR, return activated sludge from the Miramar (FL) WWTF was used to seed the MBR pilot due to its high content of Bio-P organisms.

Table 3.1
MBR Scheme: Test Program Summary

			BNR + MBR				RO
Test Condition	**Description**	**Duration days**	**Target MLSS (mg/L)**	**Target Alum Dose (mg/L)**	**Target Methanol Dose (mg/L)**	**Target Flux Rate (gfd)**	**Target Flux Rate (gfd)**
MBR-1	Biological Nitrogen and Phosphorous Removal	60	7,000	None	None	22	12
MBR-2	Biological & Chemical Nitrogen and Phosphorous Removal	7	7,000	11	20	22	12

Identifying operational and design criteria for this process scheme was not the primary objective of this pilot and therefore treatment units were generally not operated under optimal conditions (ie, most economical). As an example, due to the unforeseen difficulty

in throttling the flow through downstream processes, the MBR membrane was operated at much higher flux rates (ie. 22 gfd) than at a typical full-scale installation. A short test run (MBR-2) using methanol and alum to increase nitrogen and phosphorus removal was developed to identify the highest nutrient removal efficiency for this treatment scheme. Due to the MBR's slow stabilization period, the evaluation of additional testing conditions was not feasible due to the project's constrained schedule.

3.1.2 Conventional Treatment Scheme

The primary goal of this process scheme's testing program was to demonstrate the ability to meet the anticipated limits by conventional treatment with nitrified secondary effluent followed by DSF (with methanol addition), UF (with alum addition), RO and UV. Unlike the previous process scheme, this pilot scheme uses chemical addition (alum) for phosphorus removal. Due to the DSF's relatively fast stabilization period, more testing conditions were evaluated using different loading rates on the DSF.

Table 3.2
Conventional Treatment Scheme: Test Program Summary

Test Condition	Description	Duration (days)	Denitrification Sand Filters		UF/RO/System		
					Alum	UF	RO
			Target Methanol Feed Ratio[(1)]	Target Loading (gpm/sf)	Target Alum Dose (ppm)	Target Flux Rate (gfd)	Target Flux Rate (gfd)
CONV-1	Low DSF loading rate w/methanol and alum addition	50	3.5:1	2	40	20-25	12
CONV-2	Medium DSF loading rate w/methanol and alum addition	10	3.5:1	3	40	20-25	12
CONV-3	High DSF loading rate w/methanol and alum addition	5	3.5:1	4	80	20-25	12
CONV-4	Medium DSF loading rate w/methanol and alum addition	5	3.5:1	3	80-120	20-25	12

(1) Dosed at a ratio of 3.5 moles of methanol per 1 mole of influent nitrate concentration.

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3.1.3 RO Scheme

Under this process scheme, the DSF was decommissioned and all chemical feeds were turned off and a test run (RO-1) using only UF and RO treatment was run. This test condition was undertaken in order to evaluate the nitrogen and phosphorus removal efficiencies using UF and RO only.

Table 3.3
RO Scheme: Test Program Summary

Test Condition	Description	Duration (days)	Denitrification Sand Filters		UF/RO/System		
					Alum	UF	RO
			Target Methanol Feed Ratio	Target Loading (gpm/sf)	Target Alum Dose (ppm)	Target Flux Rate (gfd)	Target Flux Rate (gfd)
RO-1	Bypass DSF- Nitrified Secondary Effluent/UF/RO	10	None	None	None	20-25	12

3.2 Operation and Equipment

The pilot system for the three process schemes was, designed, constructed and started up as a cooperative effort between Hazen and Sawyer and CP WWTF staff. The pilot testing for this project was conducted over a six month period (actual operation of the pilot equipment-not including startup). The pilot plant was operated 24-hours/day, 7 days/week during the length of the project. Equipment descriptions and basic design criteria for the major process components in each pilot scheme are included in Appendix A. Process and Instrumentation Diagrams (P&IDs) for each process scheme are included in Appendix B (see Figures B-1, B-2, B-3). The P&IDs also show sample port locations. Photographs of the pilot equipment are included in Appendix C.

Hazen and Sawyer directed and conducted the pilot testing; including operation and maintenance (O&M), on-line monitoring of key parameters, sample collection and coordination of sample anyalyses. Separation Processes Inc. (SPI) assisted with the UF and RO membranes process control. CP WWTF staff assisted with O&M and sampling and performed the majority of the laboratory analyses. Certain specific analyses were performed by Florida Environmental Laboratories (Ft. Lauderdale, FL).

During each testing period several parameters were monitored through sample collection (grab and 24-hour composite) and on-line monitoring. An online UV nitrate sensor (Hach Nitratax) was used for TN process control. Process control parameters were monitored on a daily basis. Tables 3.4, 3.5 and 3.6 provide the Sampling and Analytical

Schedule for the key parameters of each pilot scheme. Operational Assistance was provided by the various equipment vendors (GE Water and Process Technologies, Aquionics, ITT-Leopold, Koch Membrane Systems, and Osmonics).

Table 3.4
MBR Scheme:
Key Parameters Sampling Analytical Schedule

Description	BOD_5	TSS	TN	TP	Fecal
MBR Influent (Sample Port C)(1)	4/week	4/week	3/week	3/week	1/week
MBR Effluent (Sample Port H)(1)	-	4/week	3/week	3/week	1/week
RO Permeate (Sample Port 5)	-	4/week	3/week	3/week	1/week
RO Concentrate (Sample Port 7)	-	4/week	3/week	3/week	1/week

(1) 24-hour composite sample

Table 3.5
Conventional Treatment Scheme:
Key Parameters Sampling Analytical Schedule

Description	BOD_5(2)	TSS	TN	TP	Fecal
Secondary Effluent (1,3)	-	4/week	3/week	3/week	1/week
DSF Effluent (Sample Port B)(1)	-	4/week	3/week	3/week	1/week
UF Effluent (Sample Port 2)(1)	-	4/week	3/week	3/week	1/week
RO Permeate (Sample Port 5)	-	4/week	3/week	3/week	1/week
RO Concentrate (Sample Port 7)	-	4/week	3/week	3/week	1/week

(1) 24-hour composite sample
(2) BOD_5 concentrations are assumed to be negligible for this process scheme
(3) Measured by CP WWTF at the injection well

Table 3.6
RO Scheme:
Key Parameters Sampling Analytical Schedule

Description	BOD_5 (2)	TSS	TN	TP	Fecal
Secondary Effluent (1,3)	-	4/week	3/week	3/week	1/week
UF Effluent (Sample Port 2)(1)	-	4/week	3/week	3/week	1/week
RO Permeate (Sample Port 5)	-	4/week	3/week	3/week	1/week
RO Concentrate (Sample Port 7)	-	4/week	3/week	3/week	1/week

(1) 24-hour composite sample

(2) BOD_5 concentrations are assumed to be negligible for this process scheme

(3) Measured by CP WWTF at the injection well

Under a separate study with Carollo Engineers, Hazen and Sawyer and SPI coordinated and performed sample collection to evaluate the toxicity and the fate of microconstituents through each process scheme. Samples were collected two times during the MBR testing and three times during the conventional treatment testing; samples were then analyzed by several commercial and university laboratories. Results of this effort will be published under a separate report.

Section 4.0
Results

Results presented in this document are limited to those considered of key importance to the goals of the pilot study and focus on the ability of each process scheme in meeting the anticipated limits of; TN < 1.5 mg/L, and TP < 0.02 mg/L. All other pertinent data can be found in Appendix D. For convenience and evaluation purposes, pilot test results have been grouped by test conditions and process schemes described earlier in Tables 3.1, 3.2 and 3.3.

4.1 MBR Scheme

4.1.1 Test Condition MBR-1: Biological Nitrogen and Phosphorus Removal w/o Methanol (θ ppm) and Alum (θ ppm) Addition

Using primary clarifier effluent as pilot plant influent, biological nitrogen and phosphorus removal was tested in the MBR followed by RO treatment. The MBR was tested at a net flux rate of 22 gallons per day per square foot (gfd) with a mixed liquor suspended solids (MLSS) concentration in the bioreactor of 7,000 mg/L and a sludge retention time (SRT) of 12 days. The RO system was first tested as a 2-stage system (6 elements in parallel, 3 elements in series), but due to the RO influent pump's flow constraints only a flux rate of 8 gfd was achieved and therefore the RO system was reduced to a 1-stage system (6 elements in series) midway through testing. The resulting flux rate was raised to 12 gfd at a 50-55% recovery rate. It should be noted that two composite samplers (24-hr) were donated by the Miami Dade Water and Sewer Department for this project towards the end of this test condition to assist in sample collection. These samplers were added at the MBR Influent and Effluent. TN and TP results are summarized in Figures 4-1 and 4-2, respectively.

As shown in Figure 4-1 and Table 4.1, pilot operation under this test condition was generally able to meet the effluent TN limit of 1.5 mg/L in most of the samples with an average RO Permeate TN concentration of 1.2 mg/L. The average MBR Influent and Effluent TN concentrations were 19.7 mg/L and 5.8 mg/L, respectively. The average overall TN removal rate was 94%.

As shown in Figure 4-2 and Table 4.1, pilot operation under this test condition was also generally able to meet the effluent TP limit of 0.02 mg/L in most samples with most of the RO Permeate TP concentration (Avg. TP of 0.02 mg/L) results below the testing

Figure 4-1
Test Condition MBR-1: Biological Nitrogen and Phosphorus Removal
w/o Methanol (0 ppm) and Alum (0 ppm) Addition
Total Nitrogen Removal

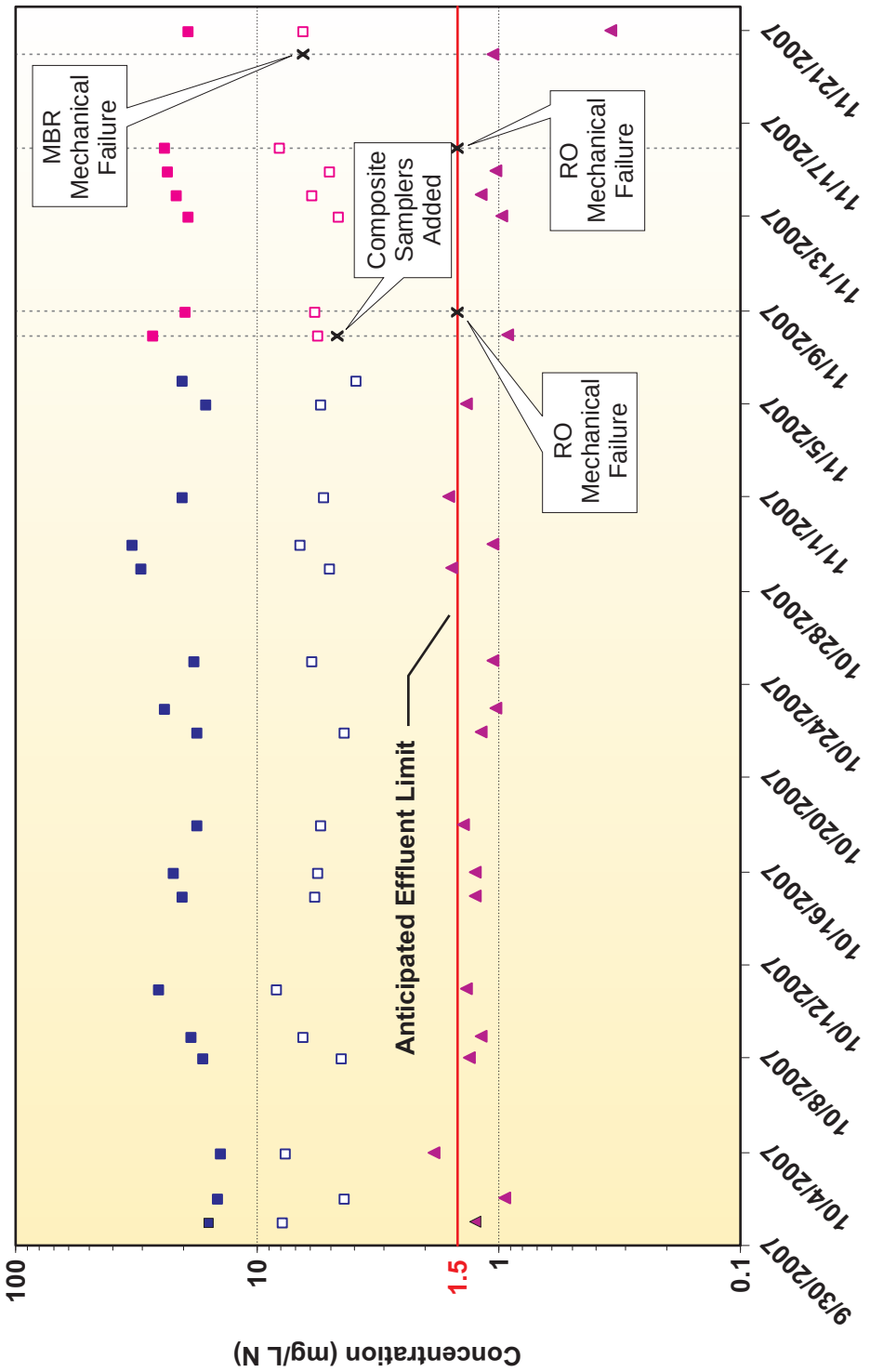

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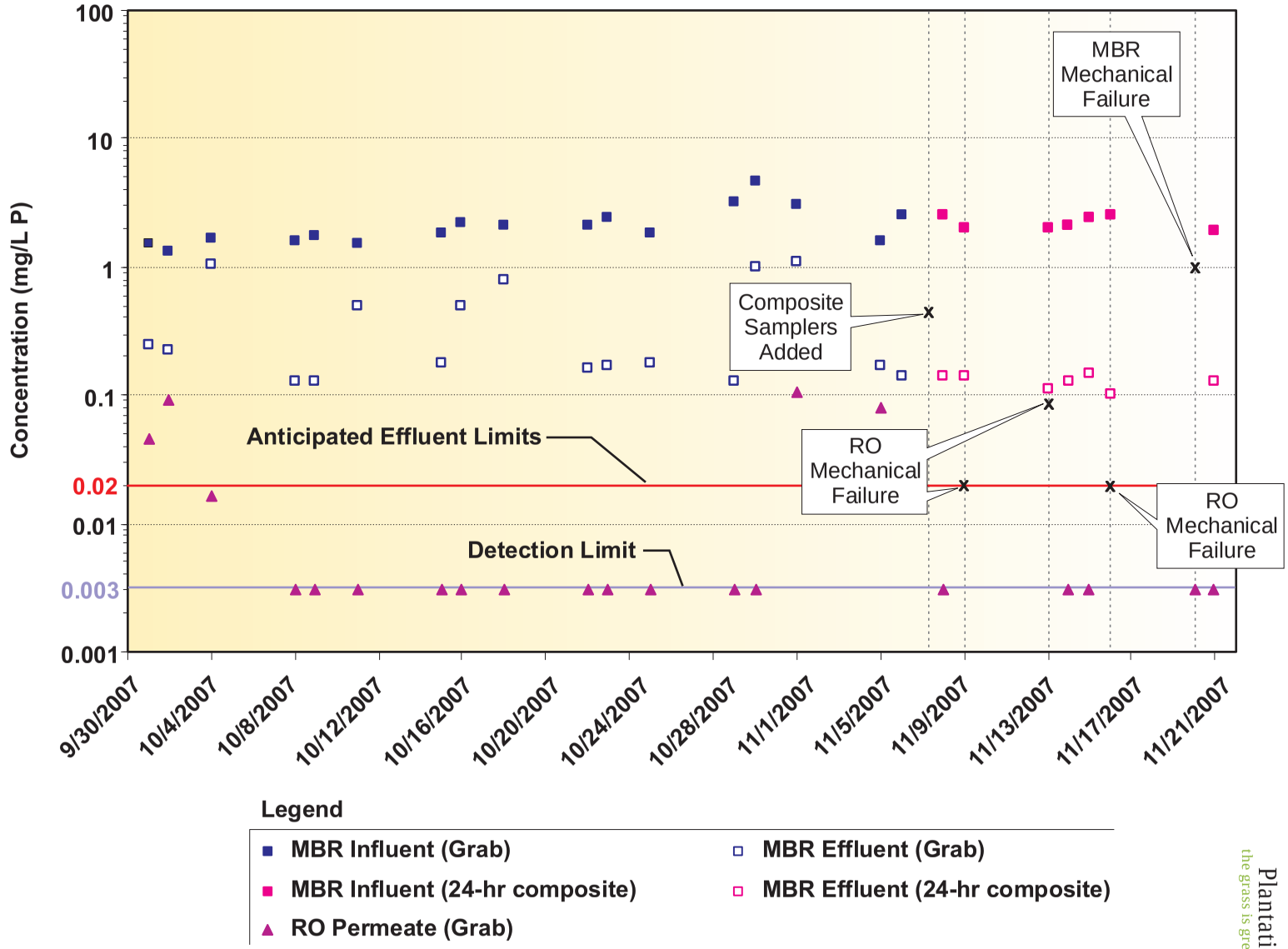
Figure 4-2
Test Condition MBR-1: Biological Nitrogen and Phosphorus Removal
w/o Methanol (0 ppm) and Alum (0 ppm) Addition
Total Phosphorus Removal



method's detection limit (<0.003 mg/L). The average MBR Influent and Effluent TP concentrations were 2.0 mg/L and 0.3 mg/L, respectively. The average RO Effluent TP concentration was 0.02 mg/L. The average overall TP removal rate was >99%.

Table 4.1
MBR-1: TN and TP Results Summary

Component	Average TN			Average TP		
	Influent (mg/L)	Effluent/ Permeate (mg/L)	Removal Rate (%)	Influent (mg/L)	Effluent/ Permeate (mg/L)	Removal Rate (%)
MBR	19.7	5.8	71	2.2	0.3	85
RO	5.8	1.2	79	0.3	0.02	94
MBR + RO	19.7	1.2	94	2.2	0.02	>99

4.1.2 Test Condition MBR-2: Biological and Chemical Nitrogen and Phosphorus Removal w/ Methanol (20 ppm) and Alum (11 ppm) Addition

Using primary clarifier effluent as pilot plant influent, biological and chemical nitrogen and phosphorus removal was tested in the MBR followed by RO treatment. Alum (11 ppm) and methanol (20 ppm) were added to the post anoxic zone in the bioreactor to increase phosphorus and nitrogen removal efficiencies, respectively. The MBR was tested at a net flux rate of 22 gfd with a MLSS concentration in the bioreactor ranging of 7,000 mg/L and an SRT of 12 days. The RO system was tested at a flux rate of 12 gfd and 50-55% recovery. TN and TP results are summarized in Figures 4-3 and 4-4, respectively.

As shown in Figure 4-3 and Table 4.2, pilot operation under this test condition was able to meet the effluent TN limit of 1.5 mg/L in most of the samples, with an average RO Permeate TN concentration of 1.2 mg/L. The average MBR Influent and Effluent TN concentrations were 19.2 mg/L and 6.0 mg/L, respectively. There was no significant increase in nitrogen removal with the methanol addition. This could be due to a low methanol dose and short testing period. Further tests at higher methanol doses and longer stabilization time would be necessary to fully evaluate biological and chemical nitrogen removal in the MBR. The average overall TN removal rate was 94%.

As shown in Figure 4-4 and Table 4.2, pilot operation under this test condition was able to meet the effluent TP limit of 0.02 mg/L with all of the RO permeate TP concentration results below the testing method's detection limit (<0.003 mg/L). The average MBR Influent and Effluent TP concentrations were 2.1 mg/L and 0.1 mg/L, respectively. There was significant increased phosphorus removal due to the alum addition. Further tests at

Figure 4-3
Test Condition MBR-2: Biological and Chemical Nitrogen and Phosphorus Removal
w/ Methanol (20 ppm) and Alum (11 ppm) Addition
Total Nitrogen Removal

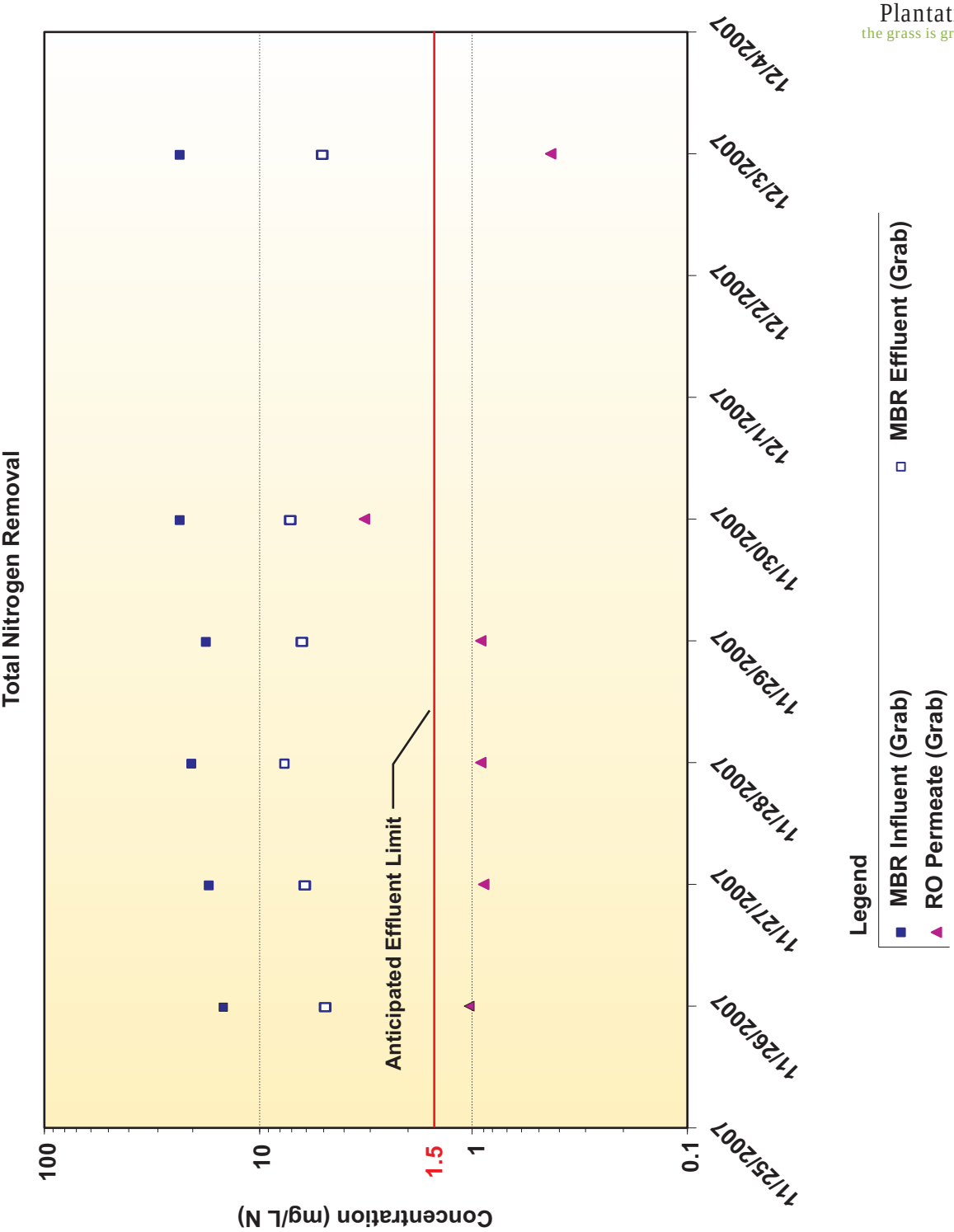


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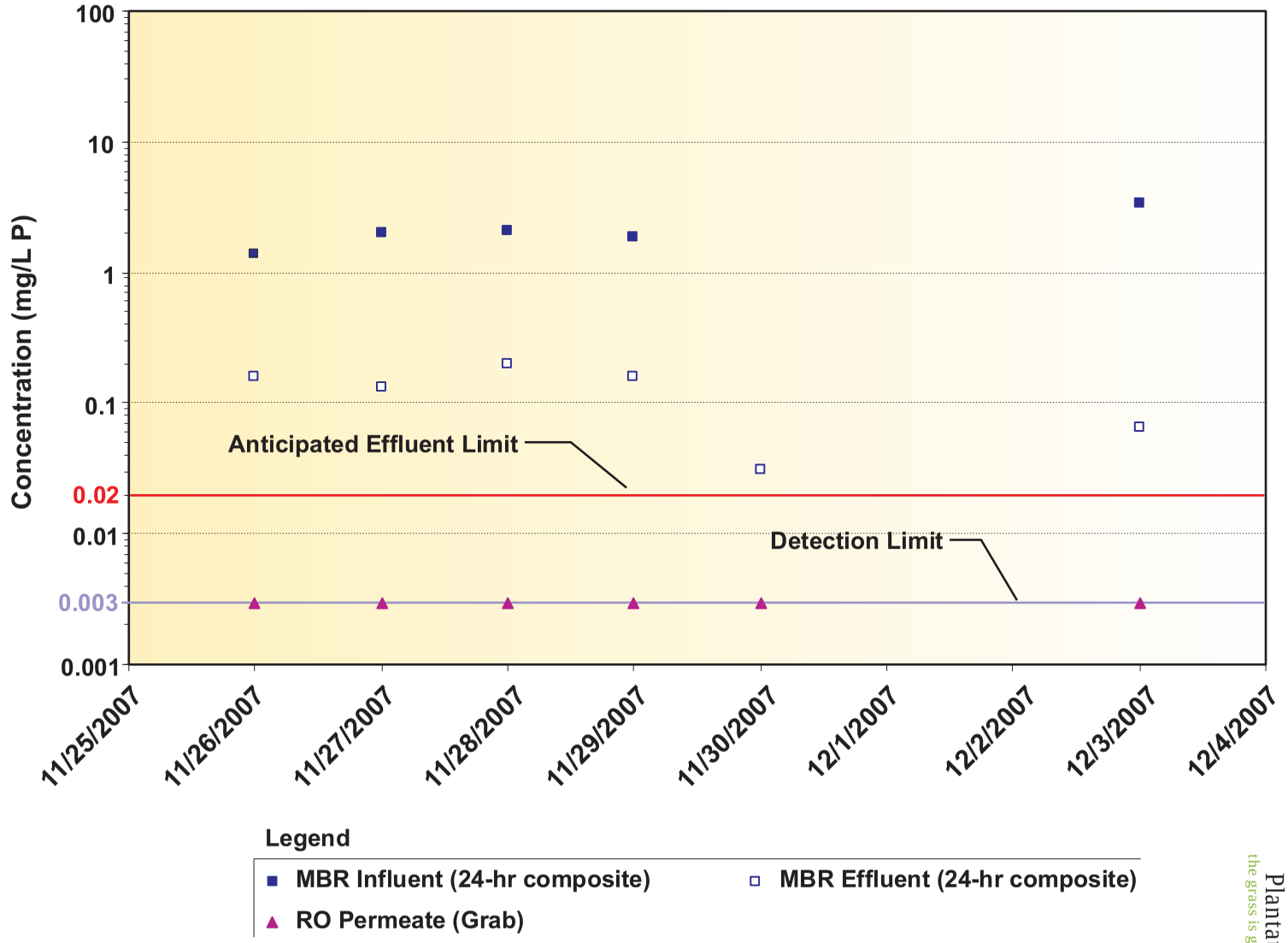
Figure 4-4
Test Condition MBR-2: Biological and Chemical Nitrogen and Phosphorus Removal w/ Methanol (20 ppm) and Alum (11 ppm) Addition
Total Phosphorus Removal



higher alum doses would still be necessary to fully evaluate biological and chemical phosphorus removal in the MBR. The average overall TP removal rate was >99%.

Table 4.2
MBR-2: TN and TP Results Summary

Component	Average TN			Average TP		
	Influent (mg/L)	Effluent/ Permeate (mg/L)	Removal Rate (%)	Influent (mg/L)	Effluent/ Permeate (mg/L)	Removal Rate (%)
MBR	19.2	6.0	69	2.1	0.1	95
RO	6.0	1.2	80	0.1	< 0.003	97
MBR + RO	19.2	1.2	94	2.1	< 0.003	>99

4.1.3 Overall Process MBR Scheme Performance

Based upon pilot test results, this process scheme is a viable option for potential full-scale implementation. This pilot scheme consistently met both TN and TP effluent limits. As shown on Table 4.3, the alum addition in test condition MBR-2 significantly increased the TP removal in the MBR compared to test condition MBR-1.

Table 4.3
MBR-1 and MBR-2: TN and TP Comparative Results Summary

Average TN					
Test Condition	MBR		RO		Test Condition Removal Rate (%)
	Influent (mg/L)	Effluent (mg/L)	Influent (mg/L)	Permeate (mg/L)	
MBR-1(1)	19.7	5.8	5.8	1.2	94
MBR-2(2)	19.2	6.0	6.0	1.2	94
Average TP					
Test Condition	MBR		RO		Test Condition Removal Rate (%)
	Influent (mg/L)	Effluent (mg/L)	Influent (mg/L)	Permeate (mg/L)	
MBR-1(1)	2.2	0.3	0.3	0.02	> 99
MBR-2(2)	2.1	0.1	0.1	< 0.003	> 99

(1) MBR-1: Methanol Dose = 0 ppm; Alum Dose = 0 ppm

(2) MBR-2: Methanol Dose = 20 ppm; Alum Dose = 11 ppm

The pilot was not optimized to minimize O&M, but operated to demonstrate the ability to meet TN and TP limits. A more extensive evaluation of the feasibility of reconfiguring the existing aeration basins at the CP WWTF into a BNR + MBR process would be necessary before full-scale implementation.

4.2 Conventional Treatment Scheme

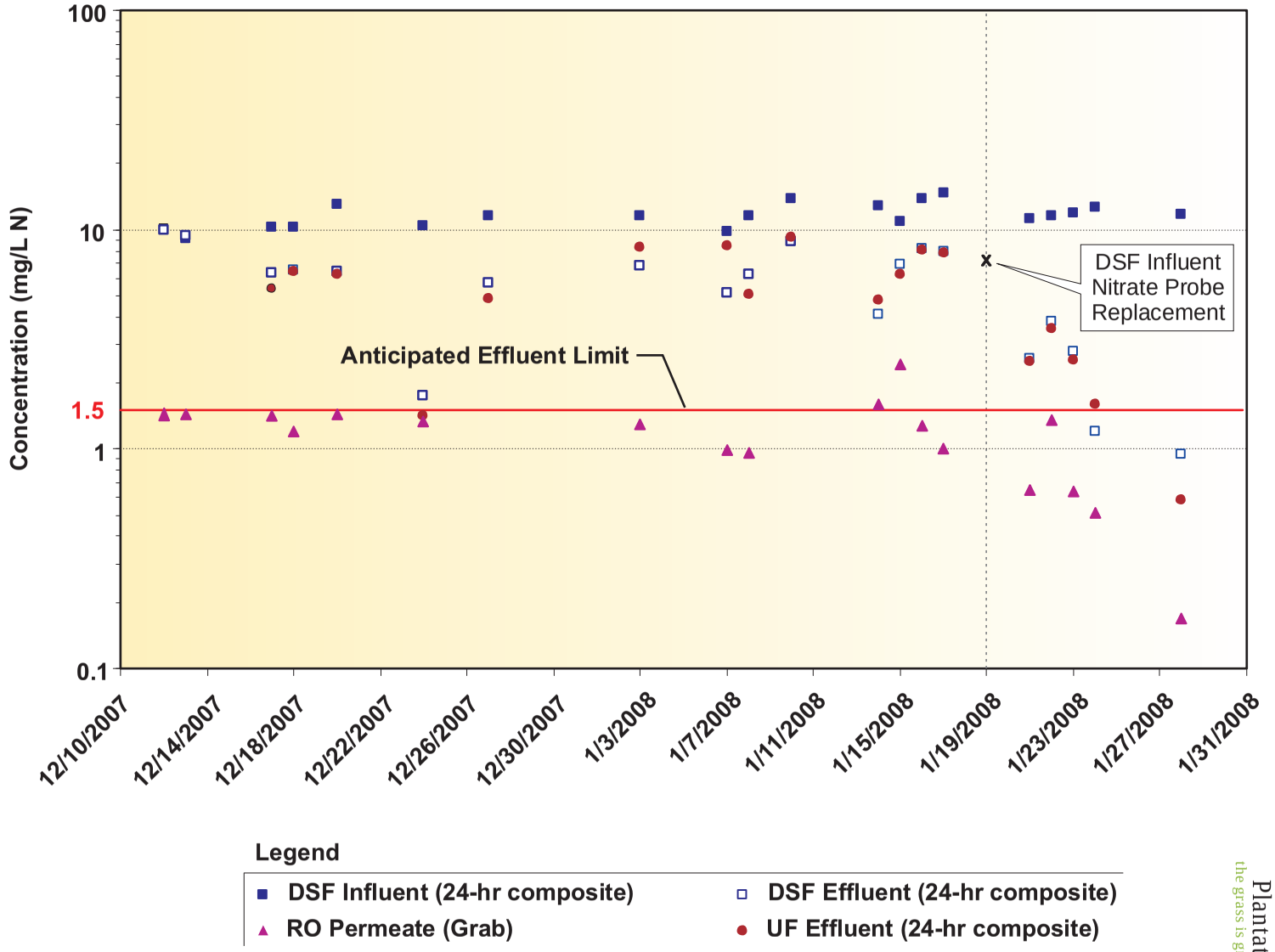
4.2.1 Test Condition CONV-1: Low DSF Loading Rate (2 gpm/sf) w/ Methanol (3.5:1 ratio) and Alum (40 ppm) Addition

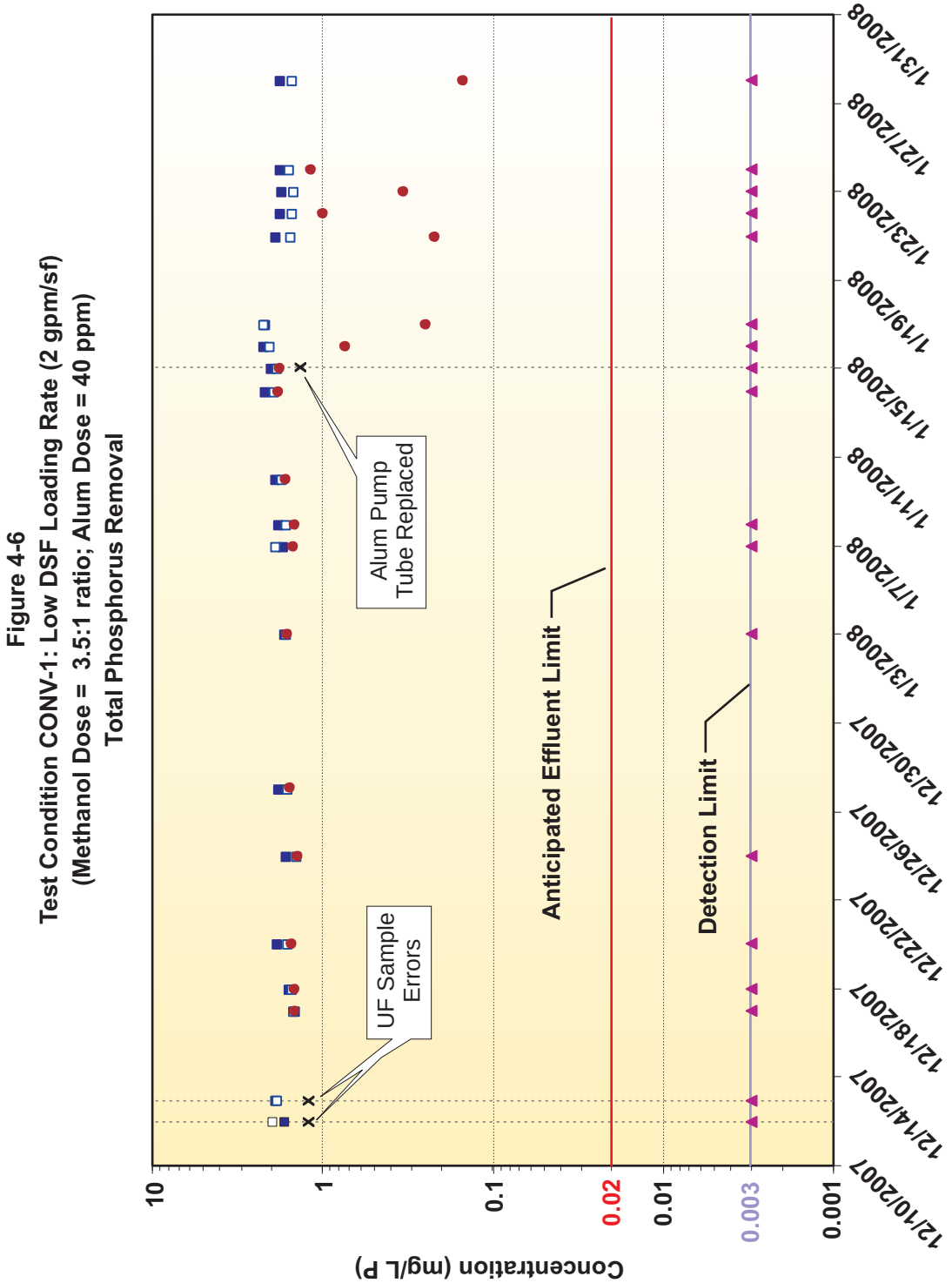
Using nitrified secondary effluent as pilot plant influent, nitrogen and phosphorus removal was tested with denitrification sand filtration, ultrafiltration and RO treatment. The sand filter was tested at a loading rate of 2 gallons per minute per square foot (gpm/sf). Methanol was dosed in the DSF based on the influent nitrate concentration at a ratio of 3.5 moles of methanol per 1 mole of nitrate (dose ranged between 11 and 29 ppm of methanol) for nitrogen removal. The UF influent was dosed with alum at 40 ppm for chemical phosphorus removal. The UF was operated at a flux rate of 20-25 gfd. The RO system was operated at a flux rate of 12 gfd and 50-55% recovery. TN and TP results are summarized in Figures 4-5 and 4-6, respectively.

As shown in Figure 4-5 and Table 4.4, pilot operation under this test condition was able to meet the effluent TN limit of 1.5 mg/L in most of the samples with an average RO Permeate TN concentration of 1.2 mg/L. The average DSF Influent and DSF Effluent TN concentrations were 11.6 mg/L and 5.6 mg/L, respectively. It should be noted that nitrification/denitrification may be occurring in the activated sludge. It was discovered early on that the influent nitrate probe was defective and a new one was ordered. As shown in Figure 4-5, the DSF Effluent TN concentration significantly decreased once the deficient nitrate probe was replaced, allowing for a more accurate methanol dose. As a result, the data during the period before the probe was replaced is deemed “non-representative” and will be disregarded. The average DSF Effluent TN concentration for the period after the probe was replaced was 2.3 mg/L. Table 4.5 presents the results for the period after the probe replacement The average UF Effluent TN concentrations were 5.2 mg/L during the period before the probe was replaced and 2.2 mg/L during the period after the probe was replaced. The average overall TN removal rate during the period after the probe was replaced was 93%.

As shown in Figure 4-6 and Table 4.4, pilot operation under this test condition was able to meet the effluent TP limit of 0.02 mg/L with all of the RO permeate TP concentration results below the testing method’s detection limit (<0.003 mg/L). The average DSF Influent and Effluent TP concentrations were 1.8 mg/L and 1.7 mg/L, respectively. The average UF Effluent TP concentration was 1.2 mg/L. It was discovered that the alum pump tubing was not operating correctly and was ultimately replaced. As shown in Figure 4-6,

Figure 4-5
Test Condition CONV-1: Low DSF Loading Rate (2 gpm/sf)
(Methanol Dose = 3.5:1 ratio; Alum Dose = 40 ppm)
Total Nitrogen Removal





41065-003R1.CDR

the UF Effluent TP concentration significantly decreased once the clogged alum pump tube was replaced, allowing for a more efficient and accurate alum dose. As a result, the data during the period before the tube was replaced is not representative and will be disregarded. The average UF Effluent TP concentration during the period after the tube was replaced was 0.6 mg/L. Table 4.5 presents the results for the period after the tube replacement.The average overall TP removal rate during the period after the tube was replaced was >99%.

Table 4.4
CONV-1: TN and TP Results Summary – All Data

Component	Average TN			Average TP		
	Influent (mg/L)	Effluent/ Permeate (mg/L)	Removal Rate (%)	Influent (mg/L)	Effluent/ Permeate (mg/L)	Removal Rate (%)
DSF	11.6	5.6	52	1.8	1.7	6
UF	5.6	5.2	7	1.7	1.2	29
RO	5.2	1.2	77	1.2	< 0.003	>99
DSF + UF + RO	11.6	1.2	90	1.8	< 0.003	>99

Table 4.5
CONV-1: TN and TP Results Summary - After Probe and Tube Replacement

Component	Average TN			Average TP		
	Influent (mg/L)	Effluent/ Permeate (mg/L)	Removal Rate (%)	Influent (mg/L)	Effluent/ Permeate (mg/L)	Removal Rate (%)
DSF	11.9	2.3	81	1.9	1.7	11
UF	2.3	2.2	4	1.7	0.6	65
RO	2.2	0.8	64	0.6	< 0.003	>99
DSF + UF + RO	11.9	0.8	93	1.9	< 0.003	>99

4.2.2 Test Condition CONV-2: Medium DSF Loading Rate (3 gpm/sf) w/ Methanol (3.5:1 ratio) and Alum (40 ppm) Addition

Using nitrified secondary effluent as pilot plant influent, nitrogen and phosphorus removal was tested with denitrification sand filtration, ultrafiltration and RO treatment. The DSF was tested at a loading rate of 3 gpm/sf. Methanol was dosed in the DSF based on the influent nitrate concentration at a ratio of 3.5 moles of methanol per 1 mole of nitrate (dose ranged between 11-29 ppm of methanol) for nitrogen removal. The UF influent was dosed with alum at 40 ppm for chemical phosphorus removal. The UF was operated

Figure 4-7
Test Condition CONV-2: Medium DSF Loading Rate (3 gpm/sf)
(Methanol Dose = 3.5:1 ratio; Alum Dose = 40 ppm)
Total Nitrogen Removal

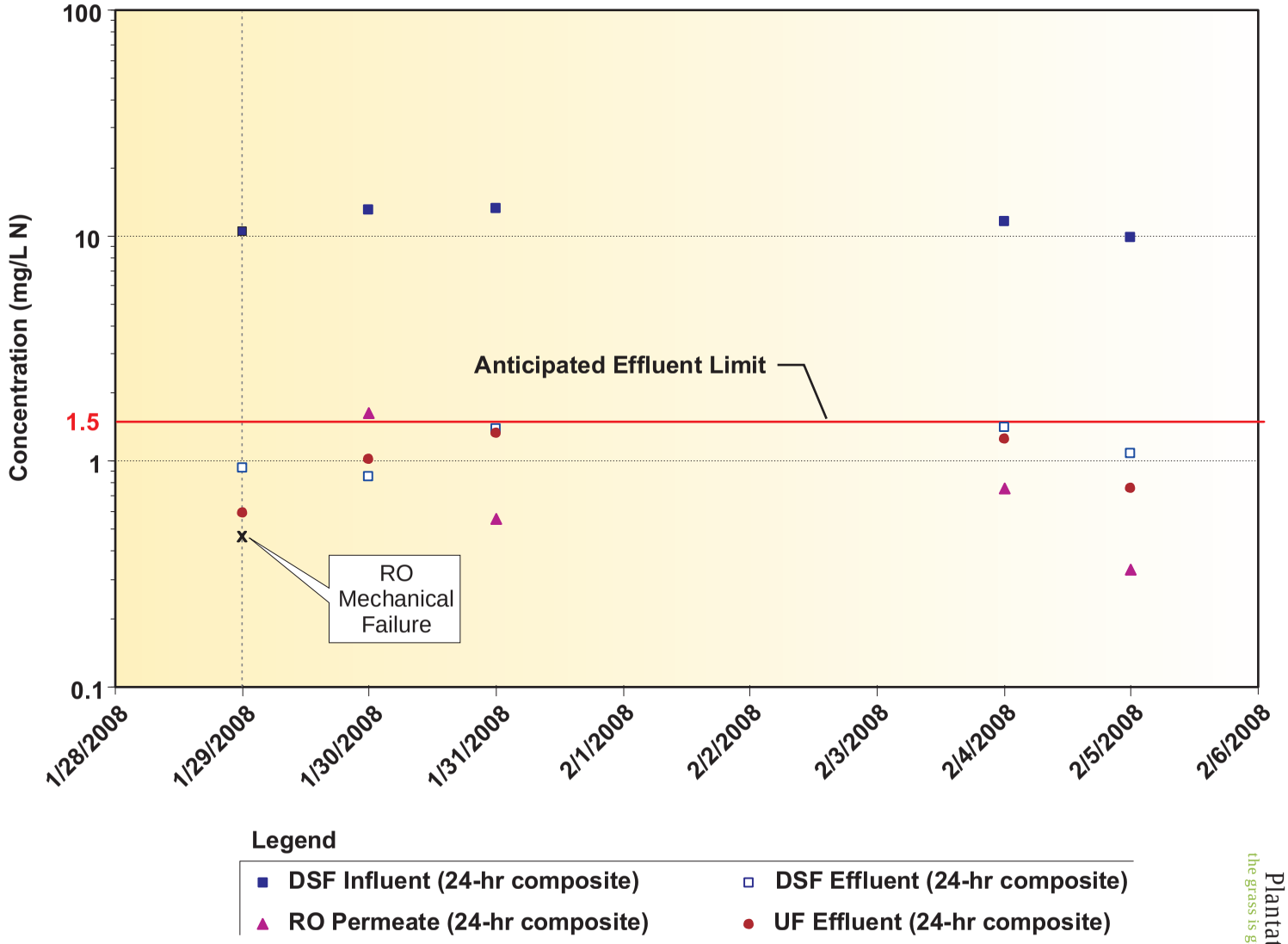
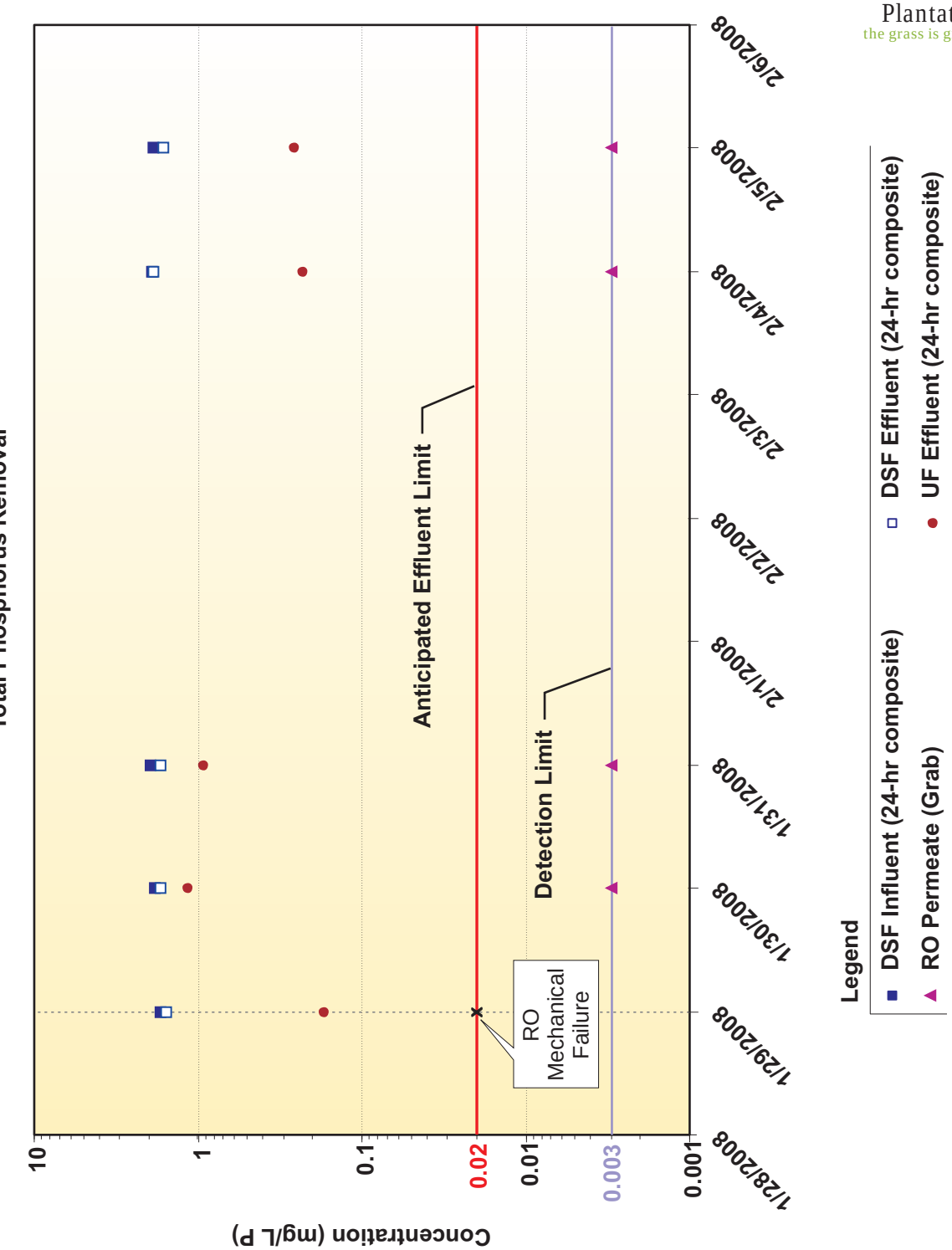


Figure 4-8
Test Condition CONV-2: Medium DSF Loading Rate (3 gpm/sf)
(Methanol Dose = 3.5:1 ratio; Alum Dose = 40 ppm)
Total Phosphorus Removal



41065-003R1.CDR

at a flux rate of 20-25 gfd. The RO system was operated at flux rate of 12 gfd and 50-55% recovery. TN and TP results are summarized in Figures 4-7 and 4-8, respectively.

As shown in Figure 4-7 and Table 4.6, pilot operation under this test condition was able to meet the effluent TN limit of 1.5 mg/L in most of the samples with an average RO Permeate TN concentration of 0.7 mg/L. The average DSF Influent and Effluent TN concentrations were 11.9 mg/L and 1.1 mg/L, respectively. As shown in Figure 4-7, the DSF and UF Effluent TN concentrations were both below the effluent TN limit, resulting in significant nitrogen removal through these processes. The average UF Effluent TN concentration was 1.0 mg/L. The average overall TN removal rate was 94%.

As shown in Figure 4-8 and Table 4.6, pilot operation under this test condition was able to meet the effluent TP limit of 0.02 mg/L with all of the RO permeate TP concentration results below the testing method's detection limit (<0.003 mg/L). The average DSF Influent and Effluent TP concentrations were 1.9 mg/L and 1.7 mg/L, respectively. The average UF Effluent TP concentration was 0.6 mg/L. As shown in Figure 4-8, there was increased phosphorus removal due to the alum addition. Further tests at higher alum doses would still be necessary to fully evaluate phosphorus removal potential in the UF with chemical addition. The average overall TP removal rate was >99%.

Table 4.6
CONV-2: TN and TP Results Summary

Component	Average TN			Average TP		
	Influent (mg/L)	Effluent/ Permeate (mg/L)	Removal Rate (%)	Influent (mg/L)	Effluent/ Permeate (mg/L)	Removal Rate (%)
DSF	11.9	1.1	91	1.9	1.7	11
UF	1.1	1.0	9	1.7	0.6	65
RO	1.0	0.7	30	0.6	< 0.003	>99
DSF + UF + RO	11.9	0.7	94	1.9	< 0.003	>99

4.2.3 Test Condition CONV-3: High DSF Loading Rate (4 gpm/sf) w/ Methanol (3.5:1 ratio) and Alum (80 ppm) Addition

Using nitrified secondary effluent as pilot plant influent, nitrogen and phosphorus removal was tested with denitrification sand filtration, ultrafiltration and RO treatment. The DSF was tested at a loading rate of 4 gpm/sf. Methanol was dosed in the DSF based on the influent nitrate concentration at a ratio of 3.5 moles of methanol per 1 mole of nitrate (dose ranged between 11-29 ppm of methanol) for nitrogen removal. The UF influent was dosed with alum at 80 ppm for chemical phosphorus removal. The UF was operated

Figure 4-9
Test Condition CONV-3: High DSF Loading Rate (4 gpm/sf)
(Methanol Dose = 3.5:1 ratio; Alum Dose = 80 ppm)
Total Nitrogen Removal

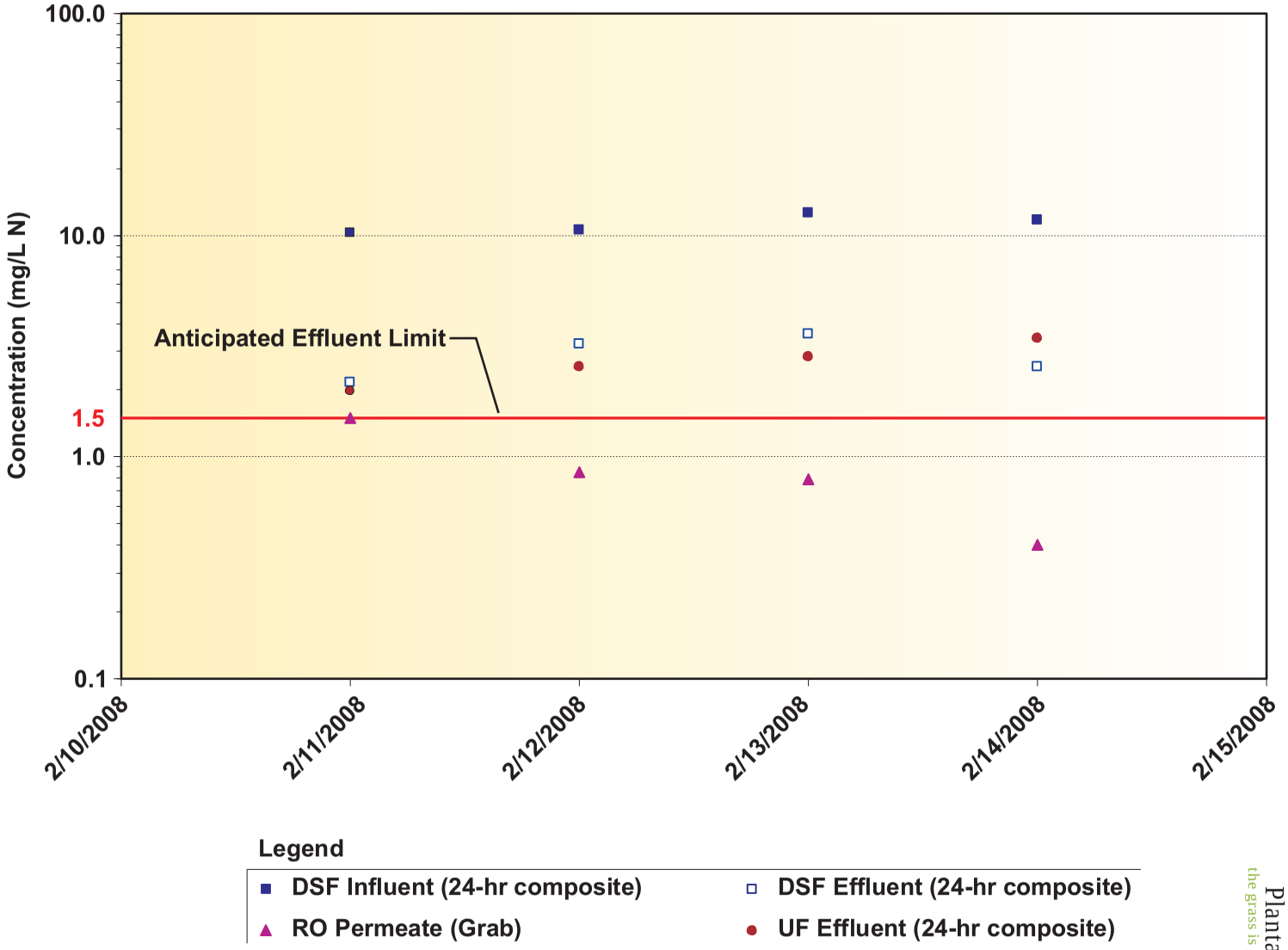
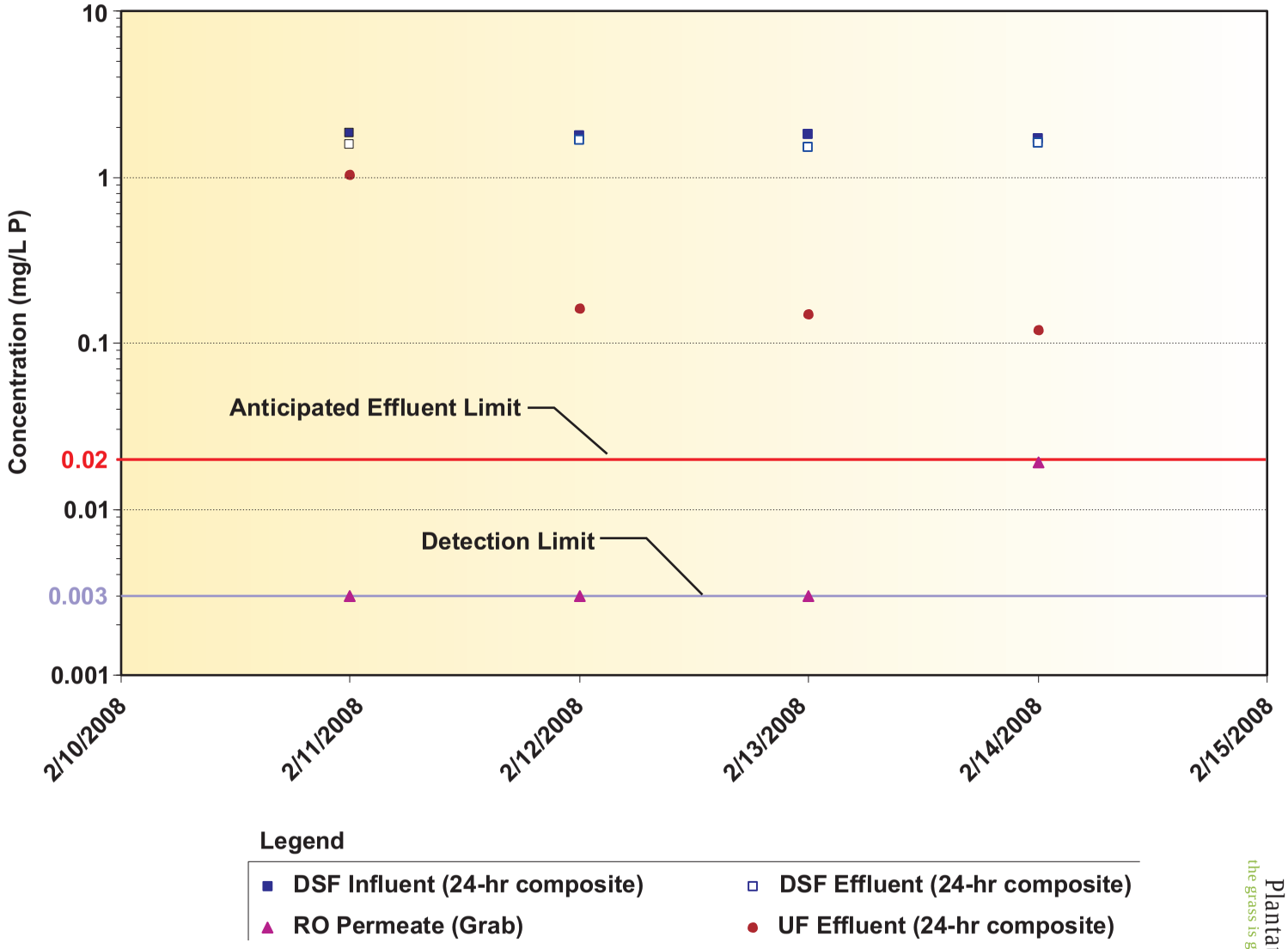


Figure 4-10
Test Condition CONV-3: High DSF Loading Rate (4 gpm/sf)
(Methanol Dose = 3.5:1 ratio; Alum Dose = 80 ppm)
Total Phosphorus Removal



at a flux rate of 20-25 gfd. The RO system was operated at flux rate of 12 gfd and 50-55% recovery. TN and TP results are summarized in Figures 4-9 and 4-10, respectively.

As shown in Figure 4-9 and Table 4.7, pilot operation under this test condition was able to consistently meet the effluent TN limit of 1.5 mg/L with an average RO Permeate TN concentration of 0.9 mg/L. The average DSF Influent and Effluent TN concentrations were 11.3 mg/L and 2.9 mg/L, respectively. The average UF Effluent TN concentration was 2.7 mg/L. The average overall TN removal rate was 92%

As shown in Figure 4-8 and Table 4.7, pilot operation under this test condition was able to meet the effluent TP limit of 0.02 mg/L in most of the samples with most of all of the RO permeate TP concentration (Avg. TP of 0.007 mg/L) results below the testing method's detection limit (<0.003 mg/L). Note that 3 out of the 4 RO permeate samples showed a non-detectable TP concentration. The average DSF Influent and Effluent TP concentrations were 1.8 mg/L and 1.6 mg/L, respectively. The average UF Effluent TP concentration was 0.4 mg/L. As shown in Figure 4-8, there was significant phosphorus removal in the UF due to the increased alum dose. Further tests at higher alum doses would still be necessary to fully evaluate phosphorus removal potential in the UF with chemical addition. The average overall TP removal rate was >99%.

Table 4.7
CONV-3: TN and TP Results Summary

Component	Average TN			Average TP		
	Influent (mg/L)	Effluent/ Permeate (mg/L)	Removal Rate (%)	Influent (mg/L)	Effluent/ Permeate (mg/L)	Removal Rate (%)
DSF	11.3	2.9	74	1.8	1.6	11
UF	2.9	2.7	7	1.6	0.4	77
RO	2.7	0.9	67	0.4	0.007	98
DSF + UF + RO	11.3	0.9	92	1.8	0.007	>99

4.2.4 Test Condition CONV-4: Medium DSF Loading Rate (3 gpm/sf) w/ Methanol (3.5:1 ratio) and High Alum (80-120 ppm) Addition

Using nitrified secondary effluent as pilot plant influent, nitrogen and phosphorus removal was tested with denitrification sand filtration, ultrafiltration and RO treatment. The DSF was tested at a loading rate of 3 gpm/sf. Methanol was dosed in the DSF based on the influent nitrate concentration at a ratio of 3.5 moles of methanol per 1 mole of nitrate (dose ranged between 11-29 ppm of methanol) for nitrogen removal. The UF influent was dosed with alum at 80 and 120 ppm for chemical phosphorus removal. The UF was operated at a flux rate of 20-25 gfd. The RO system was operated at a flux rate of 12 gfd

Figure 4-11
Test Condition CONV-4: Medium DSF Loading Rate (3 gpm/sf)
(Methanol Dose = 3.5:1 ratio; Alum Dose = 80-120 ppm)
Total Nitrogen Removal

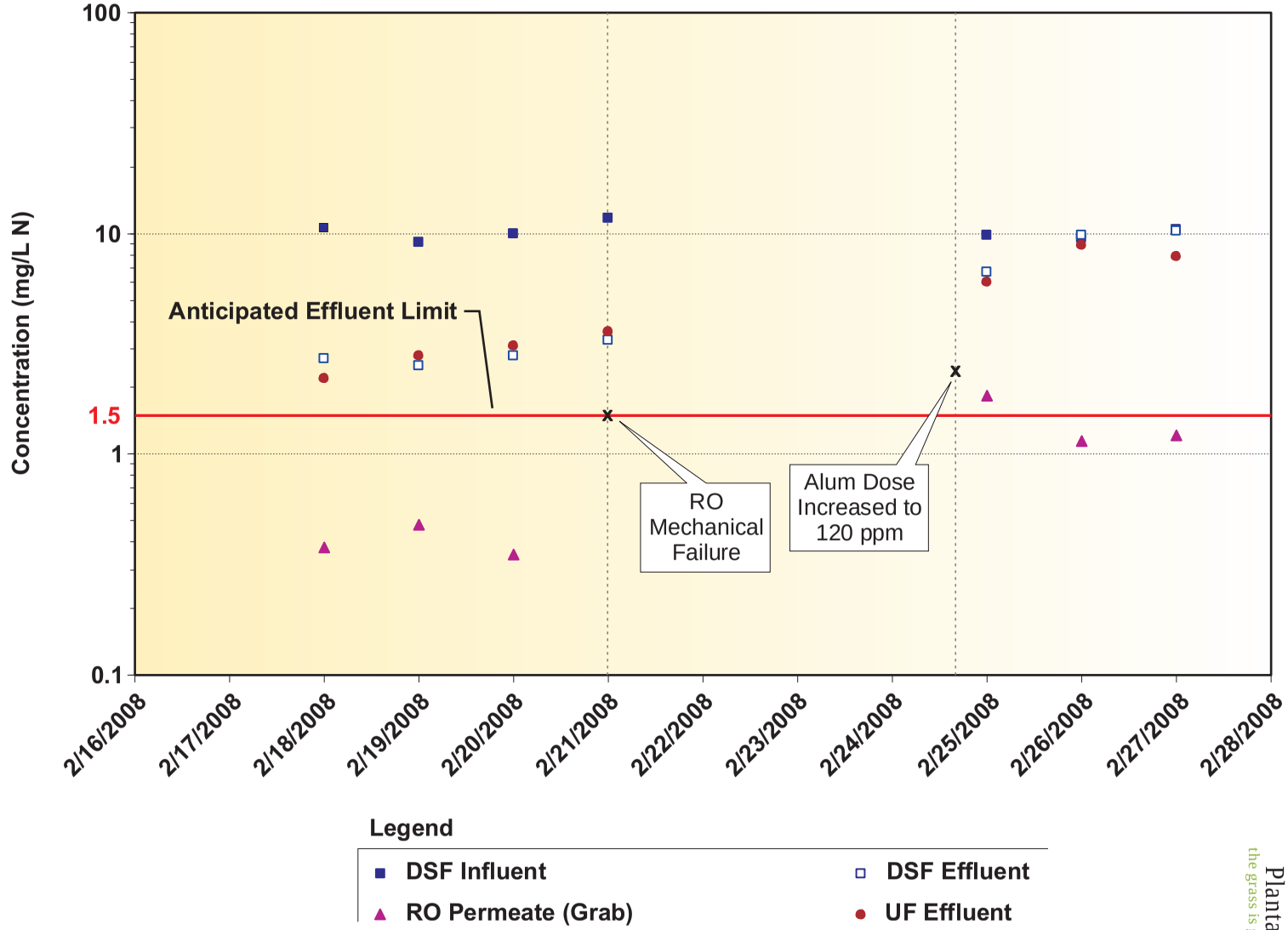
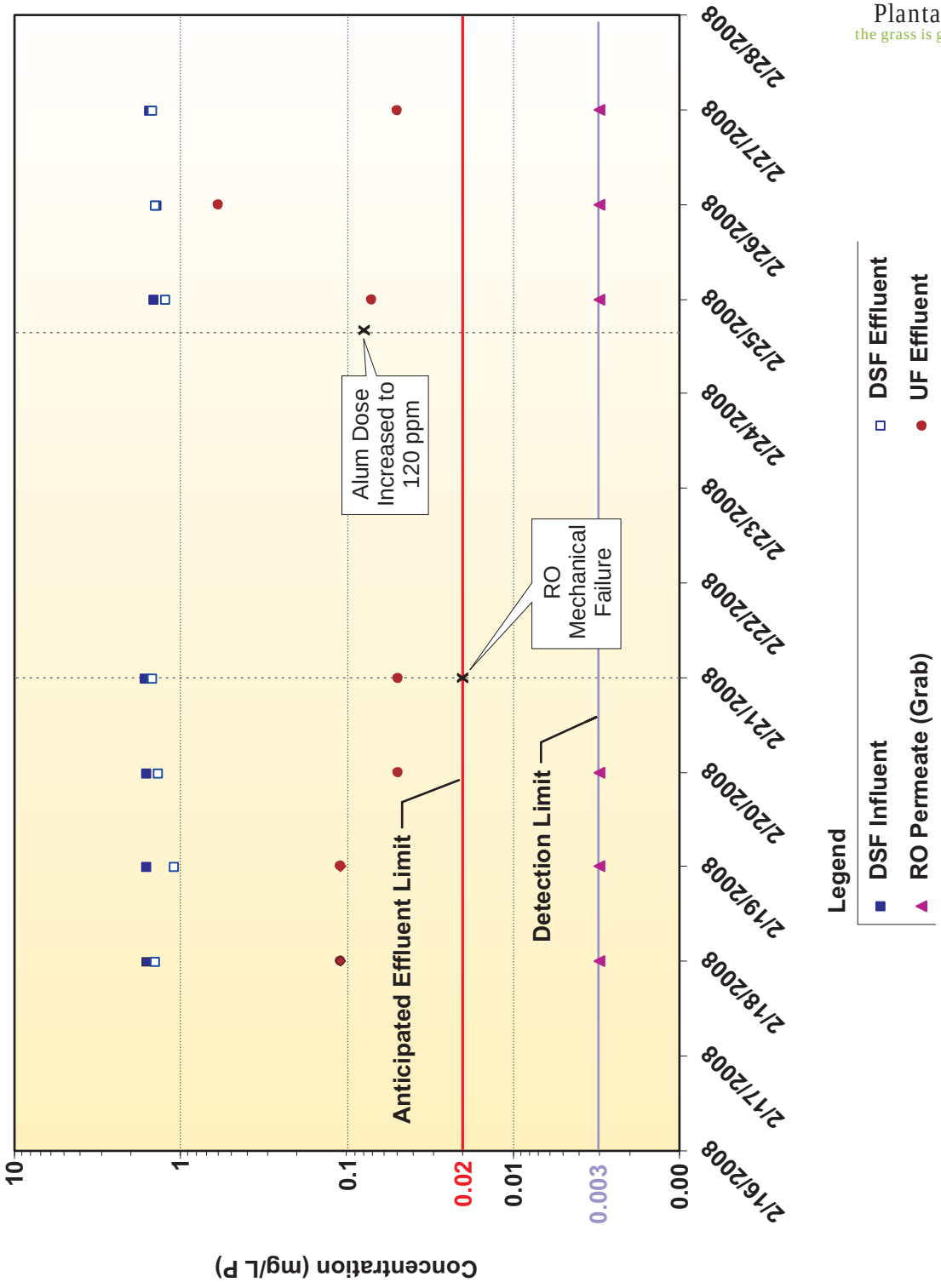


Figure 4-12
Test Condition CONV-4: Medium DSF Loading Rate (3 gpm/sf)
(Methanol Dose = 3.5:1 ratio; Alum Dose = 80-120 ppm)
Total Phosphorus Removal



41065-003R1.CDR

and 50-55% recovery. TN and TP results are summarized in Figures 4-11 and 4-12, respectively.

As shown in Figure 4-11 and Table 4.8, pilot operation under this test condition was able to meet the effluent TN limit of 1.5 mg/L in most samples with an average RO Permeate TN concentration of 0.9 mg/L. The average DSF Influent and Effluent TN concentrations were 11.3 mg/L and 2.9 mg/L, respectively. The average UF Effluent TN concentration was 2.7 mg/L. The average overall TN removal rate was 92%.

As shown in Figure 4-12 and Table 4.8, pilot operation under this test condition was able to meet the effluent TP limit of 0.02 mg/L with all of the RO permeate TP concentration results below the testing method's detection limit (<0.003 mg/L). The average DSF Influent and Effluent TP concentrations were 1.8 mg/L and 1.6 mg/L, respectively. The average UF Effluent TP concentration was 0.4 mg/L. As shown in Figure 4-12, there was significant phosphorus removal in the UF due to the increased alum dose with TP concentrations as low as 0.05 mg/L. Increase in alum dose from 80 ppm to 120 ppm did show an appreciable improvement in TP removal in the UF with removal rates increasing from 77% to 89%, respectively. Further tests at these alum doses would still be necessary to fully evaluate phosphorus removal potential in the UF with chemical addition. The average overall TP removal rate was >99%.

Table 4.8
CONV-4: TN and TP Results Summary

	Average TN			Average TP		
Component	Influent (mg/L)	Effluent/ Permeate (mg/L)	Removal Rate (%)	Influent (mg/L)	Effluent/ Permeate (mg/L)	Removal Rate (%)
DSF	10.2	5.4	46	1.5	1.4	12
UF	5.4	4.9	10	1.4	0.1	89
RO	4.9	0.8	83	0.1	< 0.003	98
DSF + UF + RO	10.2	0.8	92	1.5	< 0.003	>99

4.2.5 Conventional Treatment Scheme Performance

Based upon pilot test results, this process scheme is a viable option for potential full-scale implementation. This pilot scheme consistently met both TN and TP effluent limits. As shown on Table 4.9, the TN removal rates decreased as the DSF loading rate increased in test conditions CONV 1-4 with the exception of CONV-1 due to the deficient influent nitrate probe.

Table 4.9
CONV 1-4: TN and TP Comparative Results Summary

Component	DSF Inf. (mg/L)	DSF Eff. (mg/L)	UF Inf. (mg/L)	UF Eff. (mg/L)	RO Inf. (mg/L)	RO Perm. (mg/L)	Test Condition Removal Rate (%)
Average TN							
CONV-1[1]	11.9	2.3	2.3	2.2	2.2	0.8	93
CONV-2	11.9	1.1	1.1	1.0	1.0	0.7	94
CONV-3	11.3	2.9	2.9	2.7	2.7	0.9	92
CONV-4[2]	10.2	5.4	5.4	4.9	4.9	0.8	92
Average TP							
CONV-1[1]	1.9	1.7	1.7	0.6	0.6	< 0.003	>99
CONV-2	1.9	1.7	1.7	0.6	0.6	< 0.003	>99
CONV-3	1.8	1.6	1.6	0.4	0.4	< 0.007	>99
CONV-4[2]	1.5	1.4	1.4	0.1	0.1	< 0.003	>99

(1) These results reflect operation after nitrate probe replacement and alum pump tube replacement.

(2) These results reflect the combined results for alum doses of 80 ppm and 120 ppm.

All test conditions had a high TP removal rate, with most of the test results below the detection limit. Table 4.10 provides a summary of the operating conditions.

Table 4.10
Summary of Operating Conditions

Test Condition	Description	Duration Days	DSF		UF/RO System
			Target Methanol Dose[(1)] mg/L)	Target Loading (gpm/sf)	Target Alum Dose (mg/L)
CONV-1	Low DSF loading rate w/methanol and alum addition	50	3.5:1	2	40
CONV-2	Medium DSF loading rate w/methanol and alum addition	10	3.5:1	3	40
CONV-3	High DSF loading rate w/methanol and alum addition	5	3.5:1	4	80
CONV-4	Medium DSF loading rate w/methanol and alum addition	5	3.5:1	3	80 and 120

(1) Dosed at a ratio of 3.5 moles of methanol per 1 mole of influent nitrate concentration.

4.2.6 Test Condition RO-1: Bypass DSF Nitrified Secondary Effluent/UF/RO w/o Methanol (θ ppm) and Alum (θ ppm) Addition

Using nitrified secondary effluent as pilot plant influent, nitrogen and phosphorus removal was tested with, ultrafiltration and RO treatment. The UF was operated at a flux rate of 20-25 gfd. The RO system was operated at a flux rate of 12 gfd and 50-55% recovery. TN and TP results are summarized in Figures 4-13 and 4-14, respectively.

As shown in Figure 4-13 and Table 4.11, pilot operation under this test condition was able to meet the effluent TN limit of 1.5 mg/L in most samples with an average RO Permeate TN concentration of 1.3 mg/L. The average UF Influent and Effluent TN concentrations were 11.0 mg/L and 10.5 mg/L, respectively. The average overall TN removal rate was 88%.

As shown in Figure 4-14 and Table 4.11, pilot operation under this test condition was able to meet the effluent TP limit of 0.02 mg/L with all of the RO permeate TP concentration results below the testing method's detection limit (<0.003 mg/L). The average UF Influent and Effluent TP concentrations were 1.8 mg/L and 1.6 mg/L, respectively. As

Figure 4-13
Test Condition RO-1: Bypass DSF Nitrified Secondary Effluent/UF/RO
(Methanol Dose = 0 ppm; Alum Dose = 0 ppm)
Total Nitrogen Removal

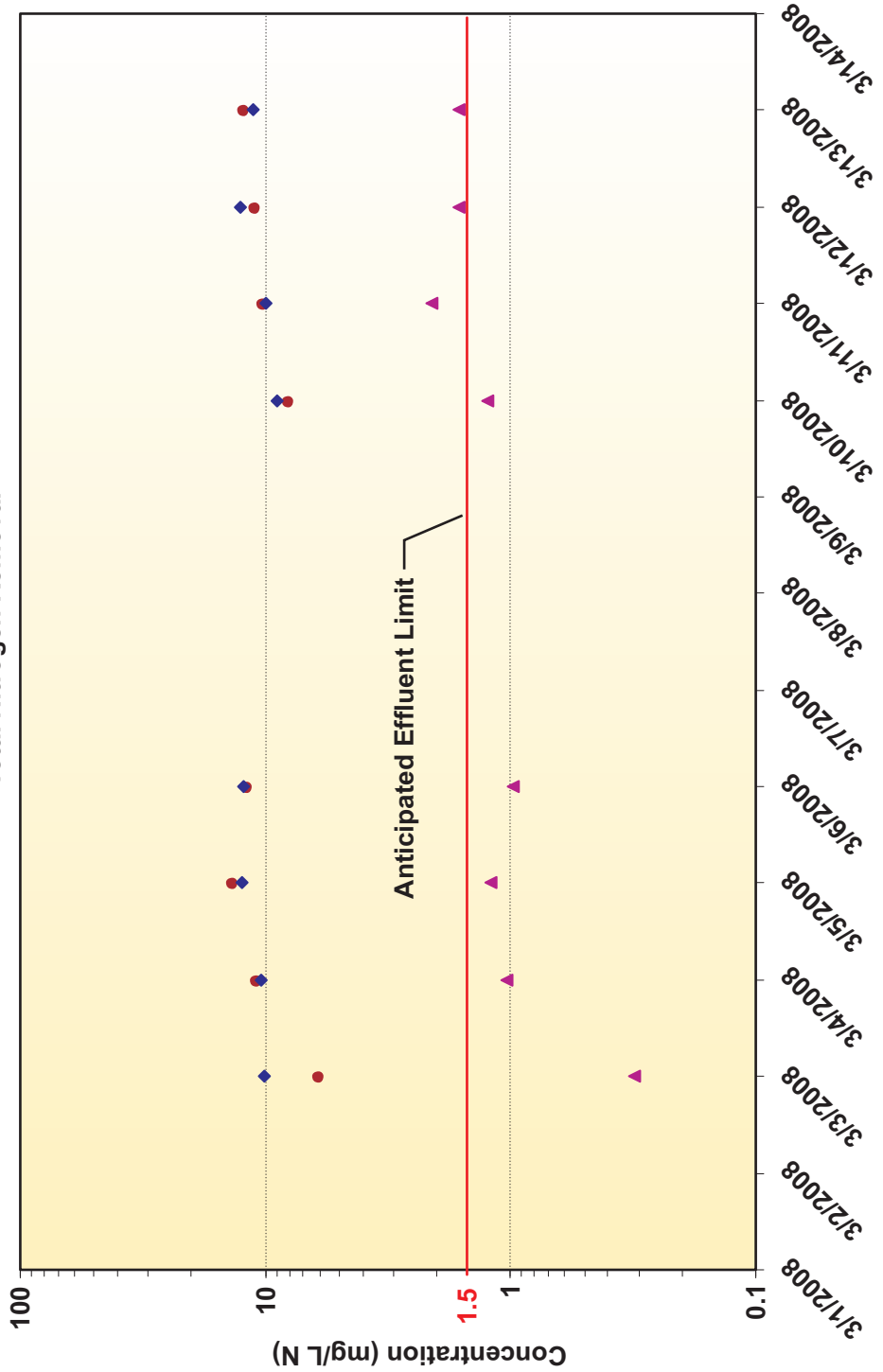


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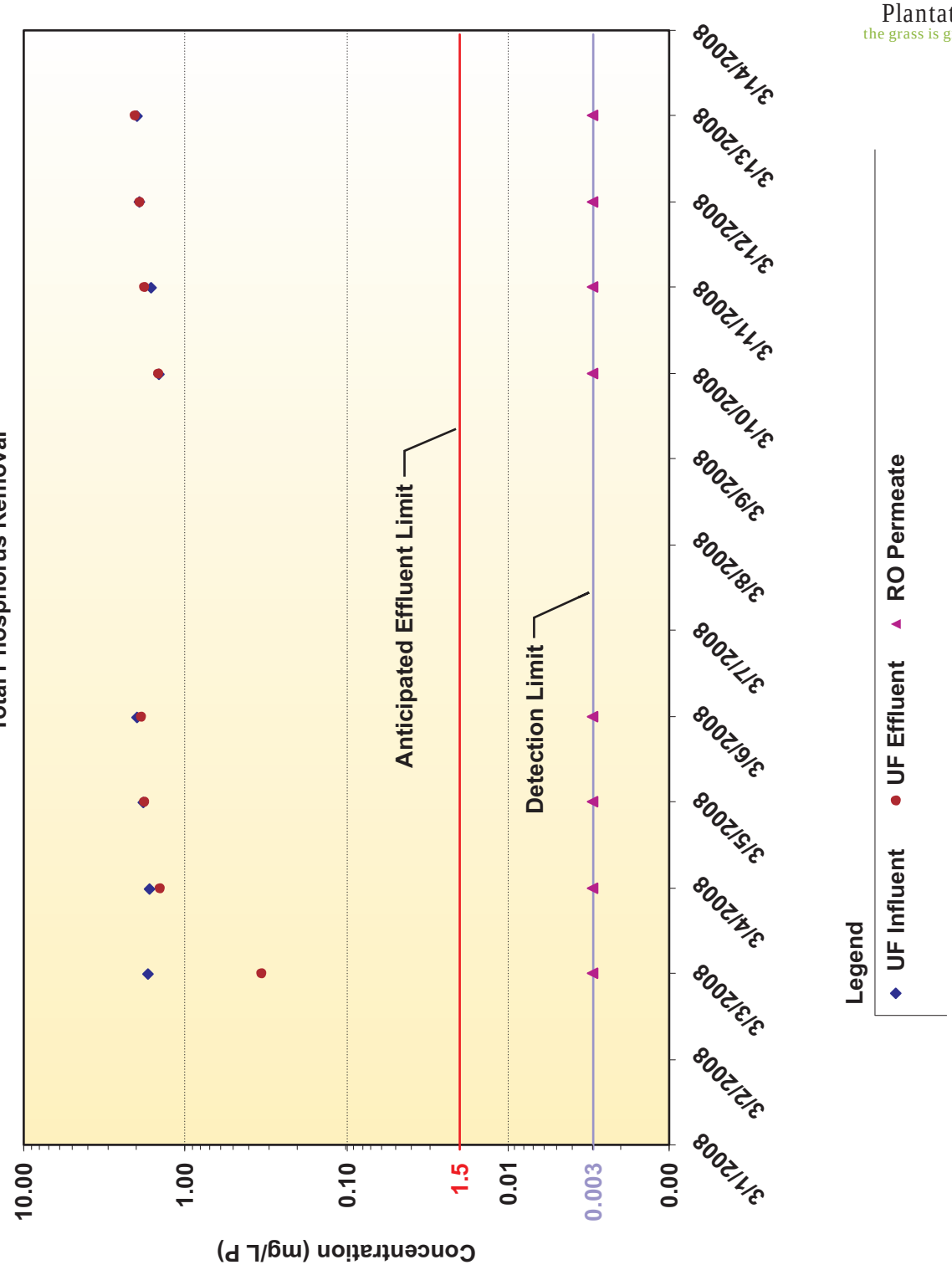
Figure 4-14
Test Condition RO-1: Bypass DSF Nitrified Secondary Effluent/UF/RO
(Methanol Dose = 0 ppm; Alum Dose = 0 ppm)
Total Phosphorus Removal



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shown in Table 4.8, the RO system was able to remove most of the influent TP, with a removal rate of >99%. The average overall TP removal rate was >99%.

Table 4.11
RO-1: TN and TP Results Summary

Component	Average TN			Average TP		
	Influent (mg/L)	Effluent/ Permeate (mg/L)	Removal Rate (%)	Influent (mg/L)	Effluent/ Permeate (mg/L)	Removal Rate (%)
UF	11.0	10.5	5	1.8	1.6	10
RO	10.5	1.3	88	1.6	< 0.003	>99
UF + RO	11.0	1.3	88	1.8	< 0.003	>99

Section 5.0
Summary

The goal of this pilot program was to evaluate potential treatment technologies and demonstrate potential compliance with the anticipated effluent limits; specifically TN < 1.5 mg/L and TP < 0.02 mg/L. Three process schemes were piloted; MBR, Conventional Treatment and RO. The pilot systems were not optimized to minimize O&M but operated only to demonstrate their ability to meet the TN and TP limits. Based on the pilot test results, all three process schemes appear to be viable options for potential full-scale implementation. As shown in Table 5.1, all three pilot schemes consistently met both TN and TP effluent limits under varying test conditions. Table 5.2 provides a summary of the operating conditions.

Table 5.1
TN and TP Comparative Results Summary

Average TN									
	MBR		DSF		UF		RO		Test Condition Removal Rate (%)
Component	Inf. (mg/L)	Eff. (mg/L)	Inf. (mg/L)	Eff. (mg/L)	Inf. (mg/L)	Eff. (mg/L)	Inf. (mg/L)	Perm. (mg/L)	
MBR-1	19.7	5.8	-	-	-	-	5.8	1.2	94
MBR-2	19.2	6.0	-	-	-	-	6.0	1.2	94
CONV-1	-	-	11.9	2.3	2.3	2.2	2.2	0.8	93
CONV-2	-	-	11.9	1.1	1.1	1.0	1.0	0.7	94
CONV-3	-	-	11.3	2.9	2.9	2.7	2.7	0.9	92
CONV-4	-	-	10.2	5.4	5.4	4.9	4.9	0.8	92
RO-1	-	-	-	-	11.0	10.5	10.5	1.3	88
Average TP									
MBR-1	2.2	0.3	-	-	-	-	0.3	0.02	>99
MBR-2	2.1	0.1	-	-	-	-	0.1	0.003	>99
CONV-1	-	-	1.9	1.7	1.7	0.6	0.6	0.003	>99
CONV-2	-	-	1.9	1.7	1.7	0.6	0.6	0.003	>99
CONV-3	-	-	1.8	1.6	1.6	0.4	0.4	0.007	>99
CONV-4	-	-	1.5	1.4	1.4	0.1	0.1	0.003	>99
RO-1	-	-	-	-	1.8	1.6	1.6	0.003	>99

Table 5.2
Summary of Operating Conditions

Test Condition	Description	Duration Days	BNR + MBR		DSF		UF/RO/ System
			Target Alum Dose (mg/L)	Target Methanol Dose (mg/L)	Target Methanol Dose[(1)] (mg/L)	Target Loading (gpm/sf)	UF Target Alum Dose (mg/L)
MBR-1	Biological Nitrogen and Phosphorous Removal	60	None	None	-	-	-
MBR-2	Biological & Chemical Nitrogen and Phosphorous Removal	7	11	20	-	-	-
CONV-1	Low DSF loading rate w/methanol and alum addition	50	-	-	3.5:1	2	40
CONV-2	Medium DSF loading rate w/methanol and alum addition	10	-	-	3.5:1	3	40
CONV-3	High DSF loading rate w/methanol and alum addition	5	-	-	3.5:1	4	80
CONV-4	Medium DSF loading rate w/methanol and alum addition	5	-	-	3.5:1	3	80-120
RO-1	Bypass DSF-Nitrified Secondary Effluent/UF/RO	10	-	-	-	-	None

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Plantation
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Appendix A

Equipment Descriptions and Operational Parameters

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Table A.1
MBR Scheme:
Equipment Description and Operational Parameters

MBR Pilot Design Criteria		Units
General Information:		
Manufacturer	Zenon	
Model	ZeeWeed 500	
Process Design:		
Module Dimensions	6.8 x 2.7 x 0.2	ft
Membrane Material	PVDF	
Pore Size	0.04	µm
Operational Parameters:		
Feed (Q)	10-14	gpm
Permeate	10-12	gpm
Recirculation	4-5Q	
Wasting	225	gal/day
SRT	12	days
Transmembrane Pressure	-1 to -8	psig
Flux Rate	22	gfd
Backpulse	30 sec every 12 min	
DO in Aeration Tank	2.0	mg/L
Electrical:		
Power Requirements	100 amp-460 V	
Physical Layout:		
Trailer Size		
Length	20'	ft
Width	8'	ft
Height	12'	ft
UF/RO/UV Pilot Trailer		**Units**
Electrical (Entire Trailer):		
Power Requirements	100 amp-480 V	
Physical Layout:		
Trailer Size		
Length	55	ft
Width	9	ft
Height	12	ft
Ultrafiltration:		
General Information:		
Manufacturer	Zenon	
Model	ZeeWeed 500	
Process Design:		
Elements	2 elements 1 cassette	#
Pore Size	0.04	µm
Operational Parameters:		
Permeate Flow	13-23	gpm
Loading Rate	12	gpm/element
Vacuum Pressure	-3 to -6	psi
Pore Size	0.04	µm
Alum Addition:		
Alum Dose	40-120	ppm

Table A.1
MBR Scheme:
Equipment Description and Operational Parameters

RO:		
General Information:		
Manufacturer	Osmotics	
Model	E4H-16K	
Operational Parameters:		
Process	1-stage (6 elements in series)	
Feed	8-10	gpm
Permeate Flow	3-6	gpm
Loading Rate	10-12	gfd
Feed Pressure	100-170	psi
Pretreatment Chloramine Dose	1.5-3	ppm
Pretreatment Antiscalant Dose	2-3	ppm
Membranes:		
Manufacturer	Koch	
Model	4820 HR	
Membrane Type	TFC-HR	
Construction	Spiral wound-fiberglass	
UV:		
General Information:		
Manufacturer	Aquionics (Berson)	
Model	InLine	
Operational Parameters:		
Dose	25-40	mJ/cm^2
Feed	3-6	gpm

Table A.2
Conventional Treatment Scheme:
Equipment Description and Operational Parameters

DFS Pilot Trailer		Units
General Information		
Manufacturer	Leopold	
Model	elimi-Nite	
Electrical:		
Power Requirements	60 amp-480 V	-
Physical Layout:		
Trailer Size		
Length	29'	ft
Width	8'-6"	ft
Height	22'	ft
Operational Parameters:		
Process Flow In & Out	8-16	gpm
Loading Rate - Min/Max	2-4	gpm/sf
Filtration Area	One 4 SF Filter	sf
Media Profile	15" (gravel) 6' (coarse sand)	ft
Methanol Dose		
UF/RO/UV Pilot Trailer		
Electrical (Entire Trailer):		
Power Requirements	100 amp-480 V	
Physical Layout:		
Trailer Size		
Length	55	ft
Width	9	ft
Height	12	ft
Ultrafiltration:		
General Information:		
Manufacturer	Zenon	
Model	ZeeWeed 500	
Process Design:		
Elements	2 elements 1 cassette	#
Pore Size	0.04	µm
Operational Parameters:		
Permeate Flow	13-23	gpm
Loading Rate	20-25	gfd
Vacuum Pressure	-3 to -6	psi
Pore Size	0.04	µm
Backpulse	30 sec every 30 min	
Alum Addition:		
Alum Dose	40-120	ppm

Table A.2
Conventional Treatment Scheme:
Equipment Description and Operational Parameters

RO:		
General Information:		
Manufacturer	Osmotics	
Model	E4H-16K	
Operational Parameters:		
Process	1-stage (6 elements in series)	
Feed	8-10	gpm
Permeate Flow	3-6	gpm
Loading Rate	10-12	gfd
Feed Pressure	100-170	psi
Membranes:		
Manufacturer	Koch	
Model	4820 HR	
Membrane Type	TFC-HR	
Construction	Spiral wound-fiberglass	
Pretreatment:		
Chloramines Dose	1.5-3	ppm
Antiscalant Dose	2-3	ppm
UV:		
General Information:		
Manufacturer	Aquionics (Berson)	
Model	InLine	
Operational Parameters:		
Dose	25-40	mJ/cm^2
Feed	3-6	gpm

Table A.3
RO Scheme:
Equipment Description and Operational Parameters

UF/RO/UV Pilot Trailer		Units
Electrical (Entire Trailer):		
Power Requirements	100 amp-480 V	
Physical Layout:		
Trailer Size		
Length	55	ft
Width	9	ft
Height	12	ft
Ultrafiltration:		
General Information:		
Manufacturer	Zenon	
Model	ZeeWeed 500	
Process Design:		
Elements	2 elements 1 cassette	#
Pore Size	0.04	µm
Operational Parameters:		
Permeate Flow	13-23	gpm
Loading Rate	20-25	gfd
Vacuum Pressure	-3 to -6	psi
Pore Size	0.04	µm
Backpulse	30 sec every 30 min	
Alum Addition:		
Alum Dose	40-120	ppm
RO:		
General Information:		
Manufacturer	Osmotics	
Model	E4H-16K	
Operational Parameters:		
Process	1-stage (6 elements in series)	
Feed	8-10	gpm
Permeate Flow	3-6	gpm
Loading Rate	10-12	gfd
Feed Pressure	100-170	psi
Membranes:		
Manufacturer	Koch	
Model	4820 HR	
Membrane Type	TFC-HR	
Construction	Spiral wound-fiberglass	
Pretreatment:		
Chloramines Dose	1.5-3	ppm
Antiscalant Dose	2-3	ppm
UV:		
General Information:		
Manufacturer	Aquionics (Berson)	
Model	InLine	
Operational Parameters:		
Dose	25-40	mJ/cm^2
Feed	3-6	gpm

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Appendix B

Pilot System
Process Flow Diagrams

41065-003B004.CDR

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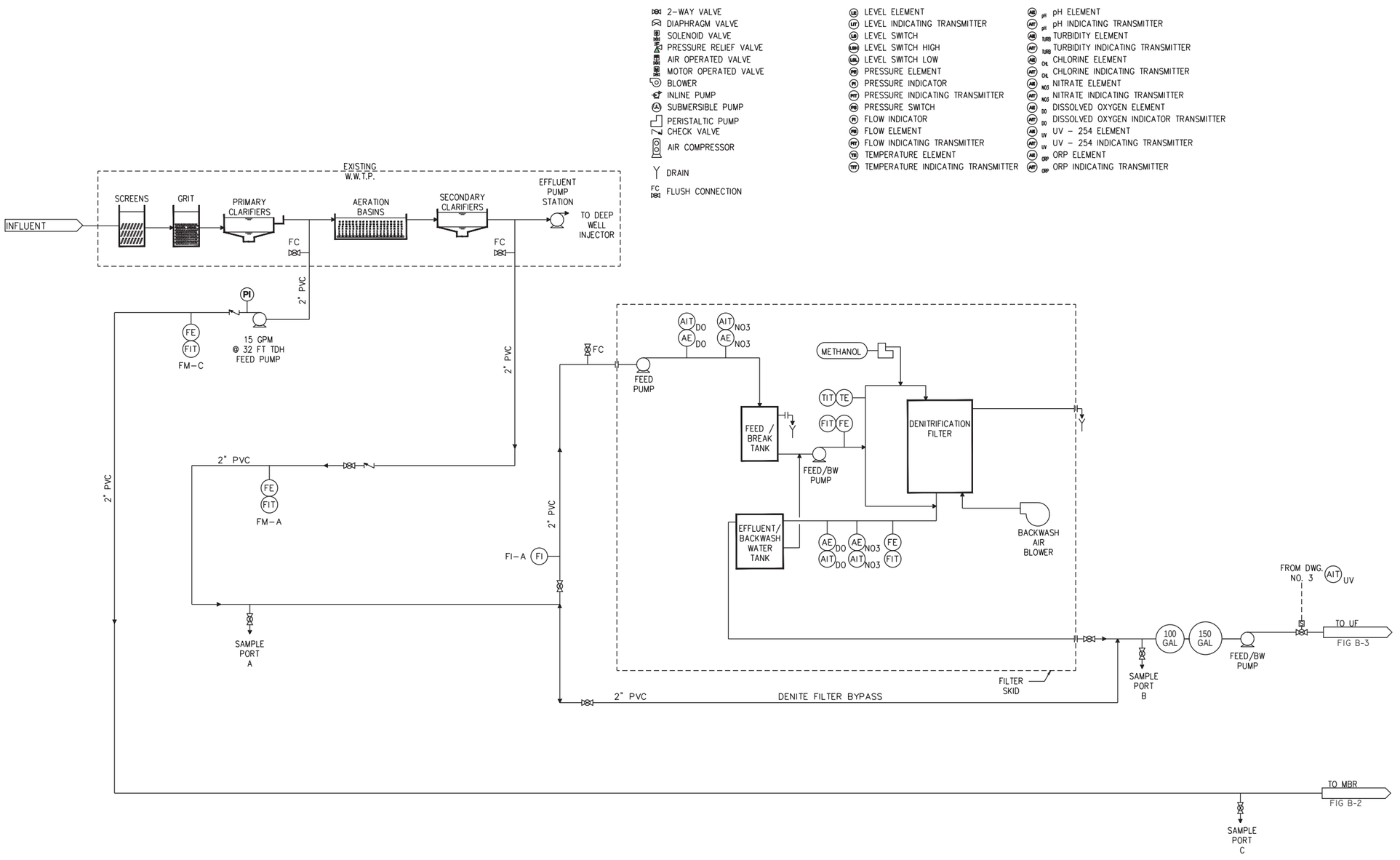
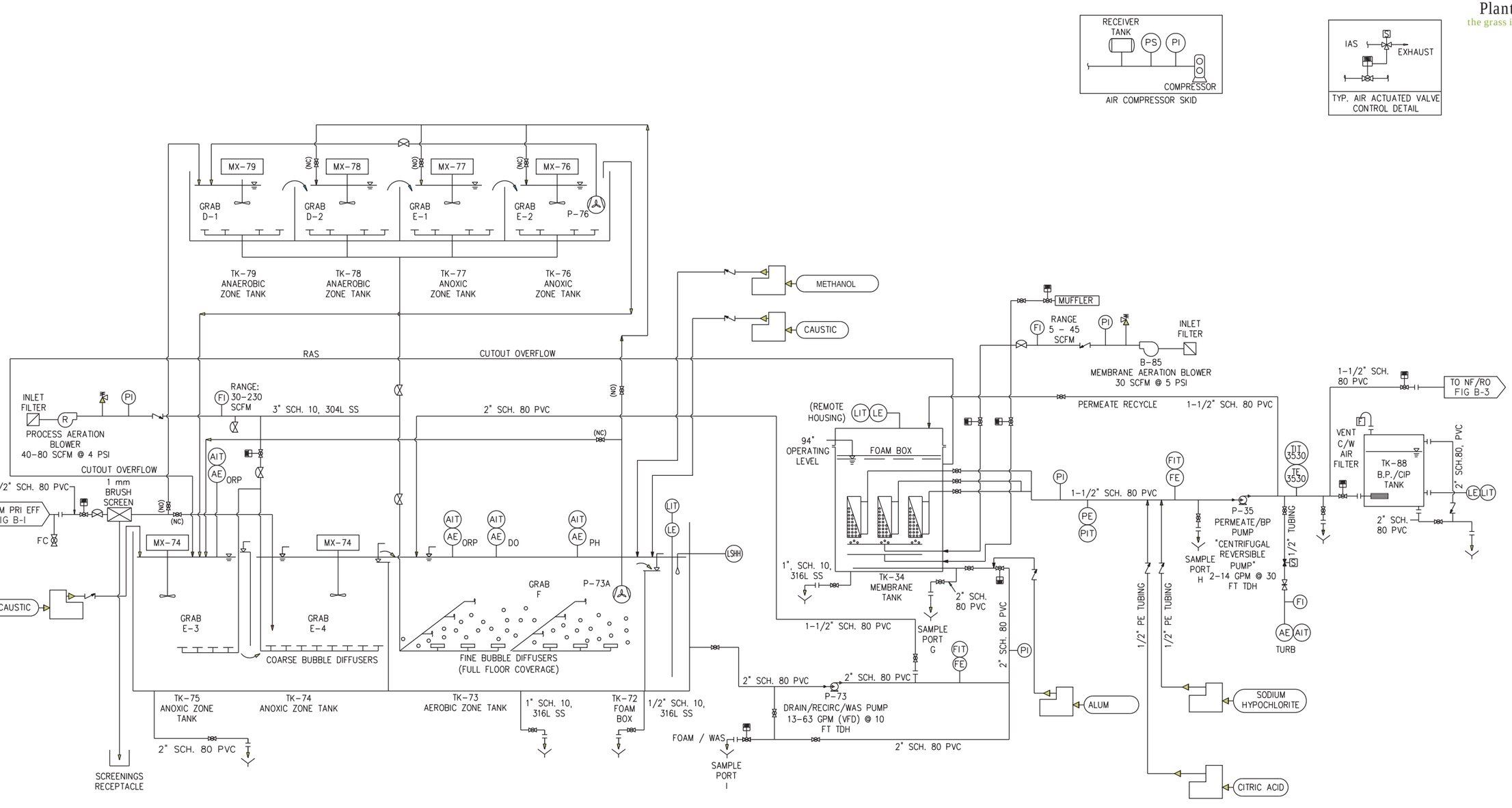


41065-003R1.CDR

Figure B-1
Pilot System Process Flow Diagram
– Conventional Treatment



41065-003R1.CDR

Figure B-2
Pilot System Process Flow Diagram
– MBR

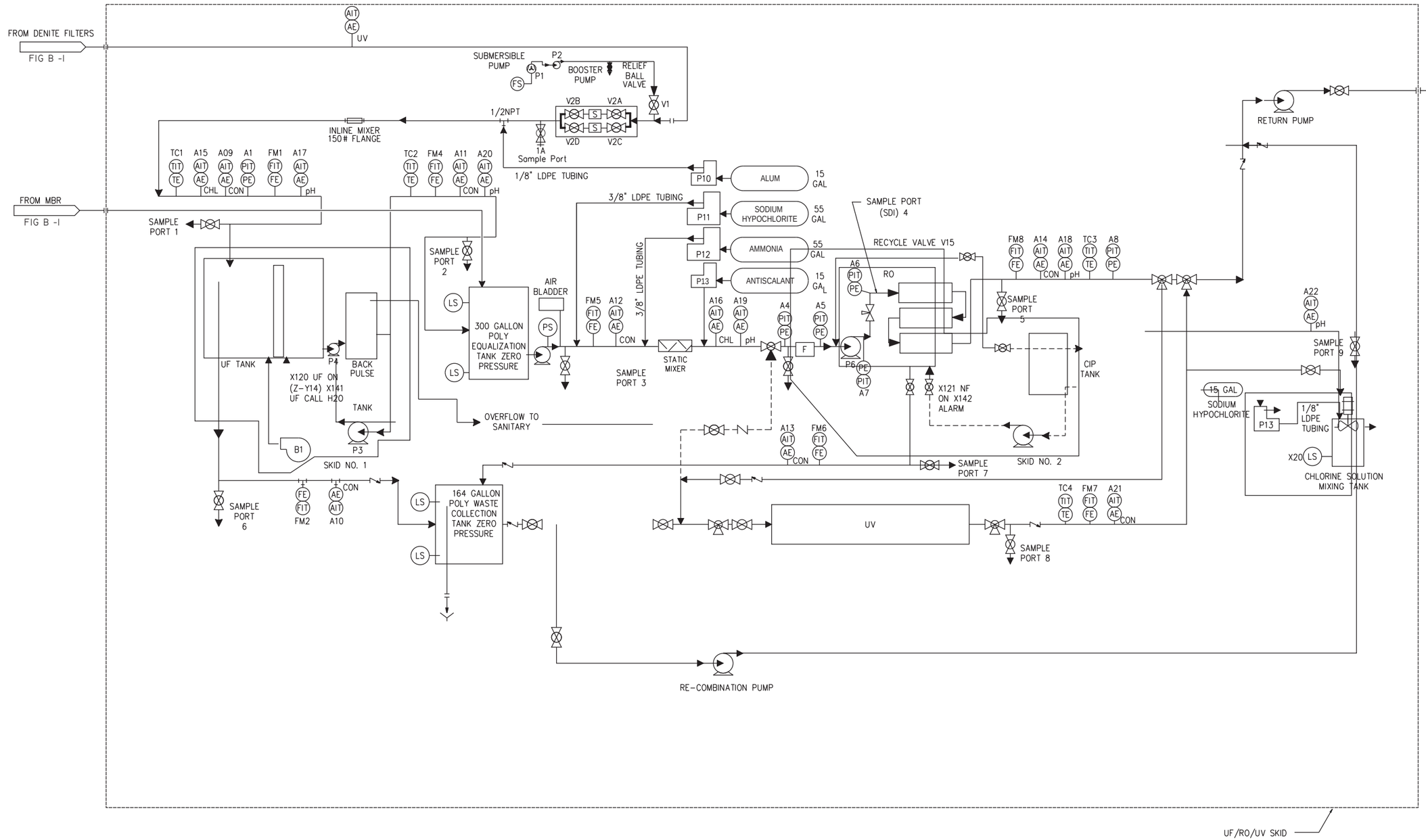


Figure B-3
Pilot System Process Flow Diagram – UF/RO/UV

41065-003R1.CDR

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Appendix C

Pilot Photgraphs

41065-003B004.CDR

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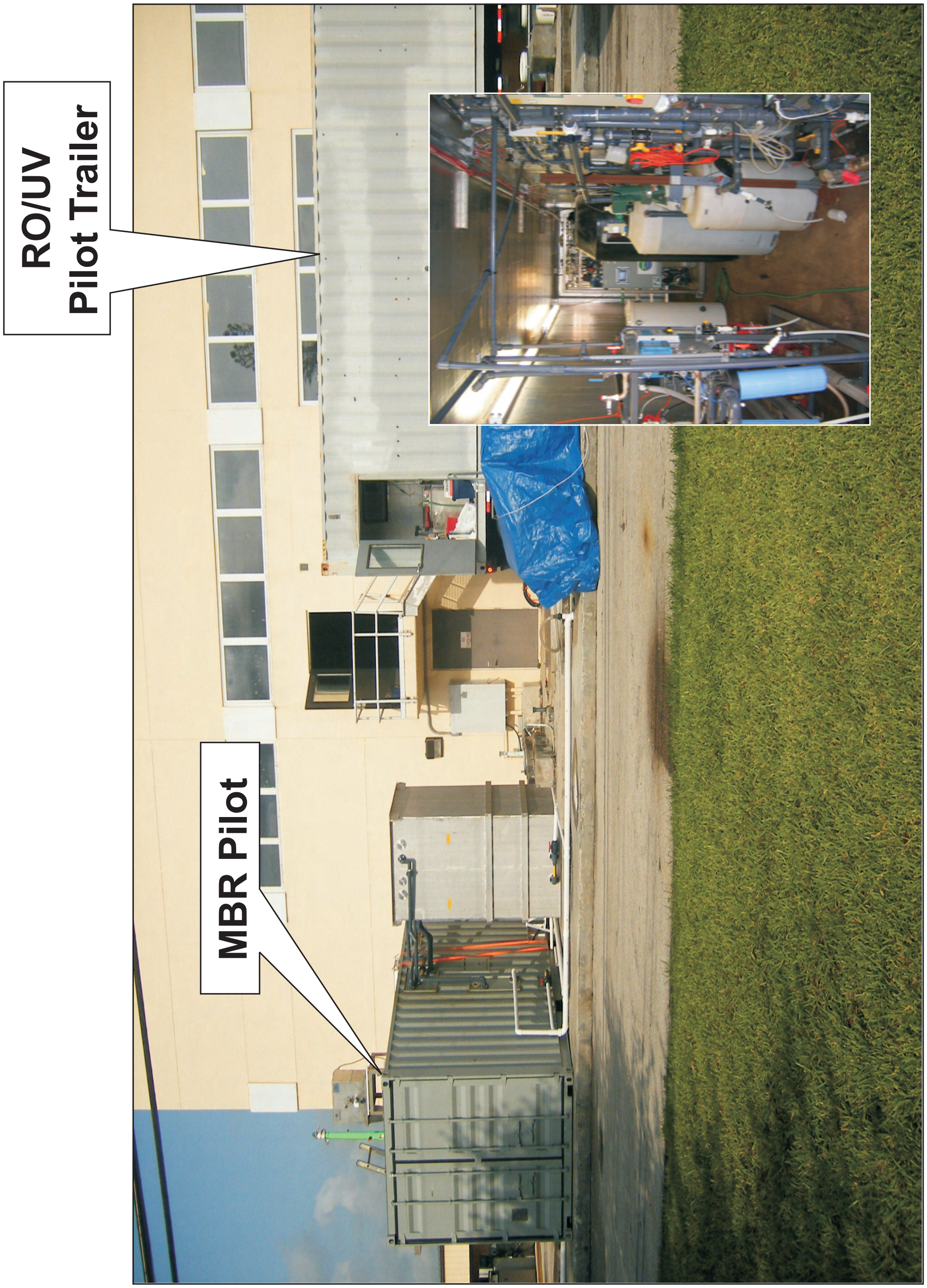

Note: RO/UV Trailer also contains UF unit although it was not used during the MBR pilot testing.

41065-003R1.CDR

Process Scheme - MBR

Process Scheme - Conventional Treatment

MBR Trailer

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UF/RO/UV Trailer

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Large Trailer

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Appendix D

Pilot Data

41065-003B004.CDR

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Table D.1
Pilot Results Summary

Component	Average BOD_5	Average TSS[1]								Fecal Coliform % Non-detectable								Average TN & TP	
	MBR	MBR		DSF		UF		RO		MBR		DSF		UF		RO		RO	
	Inf.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Perm.	Conc.	Inf.	Eff.[2]	Inf.	Eff.	Inf.	Eff.[2]	Perm.	Conc.	TN	TP
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(mg/L)	(mg/L)
MBR-1	91.7	47.5	33.6	-	-	-	-	1.0	1.3	0	50	-	-	-	-	100	-	2.2	0.3
MBR-2	91.7	45.6	32.4	-	-	-	-	1.0	1.2	0	0	-	-	-	-	100	-	2.1	0.1
CONV-1	-	-	-	7.4	2.0	-	1.3	1.0	1.2	-	-	0	-	-	0	100	-	13.2	2.6
CONV-2	-	-	-	7.6	2.0	-	1.3	1.0	1.2	-	-	0	-	-	0	100	-	2.8	1.2
CONV-3	-	-	-	10.2	1.0	-	1.4	1.0	2.0	-	-	0	-	-	0	100	-	8.0	1.0
CONV-4	-	-	-	8.6	1.0	-	3.2	1.0	1.4	-	-	0	-	-	0	100	-	10.3	0.4
RO-1	-	-	-	-	-	9.3	1.8	1.0	1.8	-	-	-	-	-	0	100	-	15.9	2.4

Note: [1] The testing method detection limit is 1.0 mg/L

[2] Small fecal counts due to growth in sampling tubes